# PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2002-036113
(43)Date of publication of application : 05.02.2002

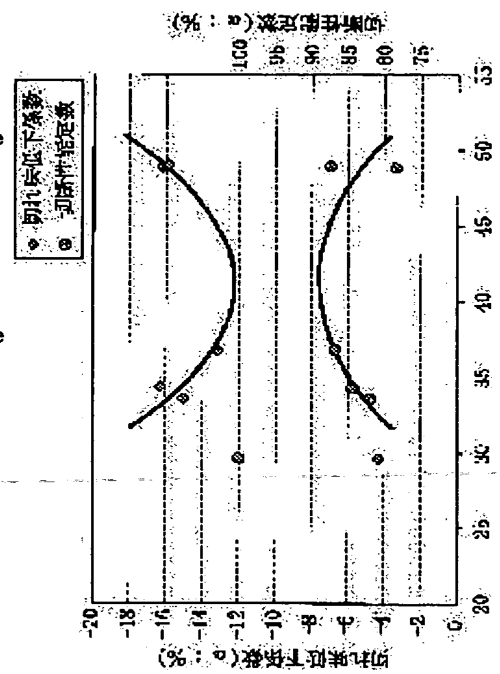
(51)Int.Cl. B24B 57/02
B24B 27/06
B28D 5/04
H01F 41/02

(21)Application number : 2000-224481
(22)Date of filing : 25.07.2000

(71)Applicant : SUMITOMO SPECIAL METALS CO LTD
(72)Inventor : KONDO SADAHIKO
MIYAJI AKIRA

## (54) METHOD OF CUTTING RARE-EARTH ALLOY AND METHOD OF MANUFACTURING RARE-EARTH ALLOY MAGNET

(57)Abstract:
PROBLEM TO BE SOLVED: To enable continuous operation for a long time by preventing a break of wire, and to provide a method of cutting a rare-earth alloy, improved in a cutting speed.
SOLUTION: A cutting fluid is supplied into a clearance between wire adhered with abrasive grains and the rare-earth alloy, while cutting the rare-earth alloy. The cutting fluid having surface tension at 25° C from 33 mN/m to 49 mN/m is used. Alloy sludge produced when cutting the rare-earth alloy is separated from the cutting fluid by magnetic force. In a range recovering the sludge, a magnet separator indicating a magnetic force of not less than 0.27 tesla is used. By controlling the temperature of the cutting fluid, the surface tension of the cutting fluid supplied to the clearance between the wire and the rare-earth alloy is adjusted.



## LEGAL STATUS

[Date of request for examination]
[Date of sending the examiner's decision of rejection]
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]
[Date of final disposal for application]
[Patent number]
[Date of registration]
[Number of appeal against examiner's decision of rejection]
[Date of requesting appeal against examiner's decision of rejection]
[Date of extinction of right]

THIS PAGE BLANK (USPTO)

SR51731 (1)


(19)日本国特許庁（ＪＰ）　(12) **公開特許公報**（Ａ）

(11)特許出願公開番号
特開2002－36113
（P2002－36113A）

(43)公開日　平成14年２月５日(2002.2.5)

| (51)Int.Cl.⁷ | 識別記号 | ＦＩ | テーマコード*(参考) |
|---|---|---|---|
| Ｂ２４Ｂ　57/02 | | Ｂ２４Ｂ　57/02 | ３Ｃ０４７ |
| 　27/06 | | 　27/06　Ｄ | ３Ｃ０５８ |
| Ｂ２８Ｄ　5/04 | | Ｂ２８Ｄ　5/04　Ｃ | ３Ｃ０６９ |
| Ｈ０１Ｆ　41/02 | | Ｈ０１Ｆ　41/02　Ｇ | ５Ｅ０６２ |

審査請求　未請求　請求項の数20　ＯＬ　（全 17 頁）

(21)出願番号　特願2000－224481(P2000－224481)

(22)出願日　平成12年７月25日(2000.7.25)



(71)出願人　000183417
住友特殊金属株式会社
大阪府大阪市中央区北浜４丁目７番19号

(72)発明者　近藤　禎彦
大阪府三島郡島本町江川２丁目15番17号
住友特殊金属株式会社山崎製作所内

(72)発明者　宮地　章
大阪府三島郡島本町江川２丁目15番17号
住友特殊金属株式会社山崎製作所内

(74)代理人　100101683
弁理士　奥田　誠司



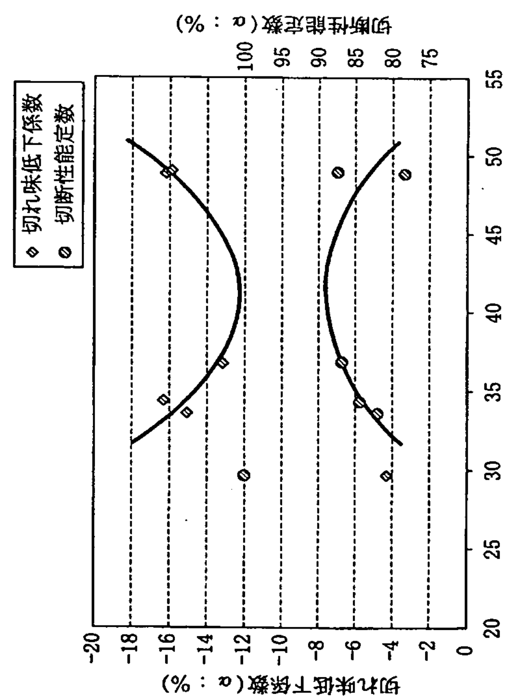
最終頁に続く


(54)【発明の名称】　希土類合金の切断方法および希土類合金磁石の製造方法


(57)【要約】

【課題】　ワイヤ切れを防止して長時間の連続運転を可能にするとともに、切断速度を向上させた希土類合金の切断方法を提供する。

【解決手段】　砥粒を固着させたワイヤと希土類合金との間に切削液を供給しながら希土類合金を切断する。２５℃の表面張力が３３ｍＮ／ｍ～４９ｍＮ／ｍにある切削液を用いる。また、希土類合金の切断する際に生じた合金スラッジを切削液内から磁力によって分離する。スラッジを回収する領域において０．２７テスラ以上の磁力を示すマグネットセパレータを用いる。切削液の温度を制御することによって、ワイヤと希土類合金との間に供給される切削液の表面張力を調節する。

1

【特許請求の範囲】

【請求項１】　砥粒を固着させたワイヤを用いる希土類合金の切断方法であって、
前記ワイヤと前記希土類合金との間に、２５℃における表面張力が３３ｍＮ／ｍ～４９ｍＮ／ｍの範囲内にある水系切削液を供給しながら前記希土類合金を切断することを特徴とする希土類合金の切断方法。

【請求項２】　前記水系切削液はグリコールを含む、請求項１に記載の希土類合金の切断方法。

【請求項３】　前記水系切削液は合成潤滑剤を含む、請求項１に記載の希土類合金の切断方法。

【請求項４】　前記水系切削液は消泡剤を含む、請求項１から３のいずれかに記載の希土類合金の切断方法。

【請求項５】　前記水系切削液はＰＨが９～１１である、請求項１から４のいずれかに記載の希土類合金の切断方法。

【請求項６】　前記水系切削液は防錆剤を含む、請求項１から５のいずれかに記載の希土類合金の切断方法。

【請求項７】　前記ワイヤは、フェノール樹脂によって固着させた砥粒を含む、請求項１から６のいずれかに記載の希土類合金の切断方法。

【請求項８】　前記水系切削液の温度を制御する工程を包含する請求項１から７の何れかに記載の希土類合金の切断方法。

【請求項９】　前記希土類合金を切断する際に生じた前記希土類合金のスラッジを含む水系切削液を回収する工程と、
前記水系切削液の温度を制御する前に、前記回収された水系切削液からスラッジを除去する工程とを包含する請求項９に記載の希土類合金の切断方法。

【請求項１０】　前記水系切削液の温度を制御する工程は、スラッジが除去された一部の水系切削液の温度を調節する工程と、前記温度が調節された一部の水系切削液と温度が調節されていない残りの水系切削液とを混合する工程とを包含し、前記混合された水系切削液を前記ワイヤと前記希土類合金との間に供給することを特徴とする請求項９に記載の希土類合金の切断方法。

【請求項１１】　前記希土類合金を切断する際に生じた前記希土類合金のスラッジを前記水系切削液内から磁力によって分離することを特徴とする請求項１から１０の何れかに記載の希土類合金の切断方法。

【請求項１２】　前記スラッジを回収する領域において０．２７テスラ以上の磁力を示すマグネットセパレータを用いることを特徴とする請求項１１に記載の希土類合金の切断方法。

【請求項１３】　外周にリング状の複数の溝が所定のピッチで形成され、回転可能に支持された複数のローラと、
前記ローラを回転させながら前記ローラの前記溝に巻き付けた前記ワイヤを走行させる駆動手段と、

2

を備えたワイヤソー装置を用いることを特徴とする請求項１から１２の何れかに記載の希土類合金の切断方法。

【請求項１４】　前記ワイヤに対して、上方から下方に向かって前記希土類合金を降下させながら前記希土類合金を切断することを特徴とする請求項１３に記載の希土類合金の切断方法。

【請求項１５】　前記希土類合金を複数のブロックに分割した状態で保持し、前記水系切削液の供給の少なくとも一部を前記複数のブロックの間隙を介して行うことを特徴とする請求項１４に記載の希土類合金の切断方法。

【請求項１６】　前記切削液の供給を、切削液槽の開口部から供給される前記切削液中に前記ワイヤを走行させることによって行うことを特徴とする請求項１４に記載の希土類合金の切断方法。

【請求項１７】　希土類合金のインゴットを作製する工程と、
請求項１から１６の何れかに記載の希土類合金の切断方法を用いて前記希土類合金のインゴットから複数の希土類合金板を分離する工程と、を包含することを特徴とする希土類合金板の製造方法。

【請求項１８】　希土類磁石合金粉末から焼結体を作製する工程と、
請求項１から１６の何れかに記載の希土類合金の切断方法を用いて前記焼結体から複数の希土類合金磁石を分離する工程と、を包含することを特徴とする希土類合金磁石の製造方法。

【請求項１９】　請求項１８に記載の希土類合金磁石の製造方法によって作製された希土類合金磁石を備えていることを特徴とするボイスコイルモータ。

【請求項２０】　前記希土類合金磁石の厚さが０．５～３．０ｍｍの範囲にあることを特徴とする請求項１９に記載のボイスコイルモータ。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、希土類合金の切断方法および切断装置に関する。より詳細には、ダイヤモンド砥粒等の超砥粒を固着させたワイヤを用いて希土類合金を切断する方法に関する。

【０００２】

【従来の技術】従来より、シリコンのインゴットから多数のウェハを切り出すためにワイヤソーを用いてインゴットを切断する技術が開発され、例えば特開平６－８２３４号公報に開示されている。このような技術によれば、走行するマルチワイヤに対して研削砥粒を含むスラリを供給しながらインゴットの切削・切断加工を実行し、一定の厚さのウェハを多数枚同時に切り出すことが可能になる。

【０００３】一方、希土類合金のインゴットを切断する方法としては、従来から、例えば回転するスライシングブレードを用いてインゴットをスライスする技術が知ら

れている。しかし、スライシングブレードで切断する方法によれば、切断刃の厚さはワイヤ径に比べて大きいため、どうしても削り代が多くなり、資源の有効利用がはかれない。

【０００４】希土類合金は、例えば磁石材料として好適に用いられている。磁石の用途は多様化し、各種の電子機器にも広く使用されているため、ワイヤソーによって希土類合金のインゴットから少ない削り代にて所定厚さのウェハを多数枚同時に作製することができれば、希土類磁石の製造コストが大幅に低減される。

【０００５】

【発明が解決しようとする課題】しかしながら、実用的なワイヤソー技術を用いて希土類合金を切断したとの報告は未だに無い。発明者らの実験によれば、遊離砥粒型ワイヤソーによる切断加工処理を希土類合金のインゴットに対して実行しようとすると、ワイヤソー加工によって発生した微粉・研削くず（きりこ若しくはスラッジ）のためにスラリ循環パイプが極めて短時間で詰まってしまう結果、ワイヤ上にスラリが供給されなくなり、ワイヤ切れが生じてしまうということがわかった。この問題を回避するためにスラリ全体を数時間ごとに完全に交換すると、スラリ交換の都度ワイヤソーによる加工を中断しなければならなくなるため、量産には適さず、実用化が不可能になる。また、スラッジは切削溝内にもたまりやすく、そのせいで切削抵抗が著しく増加し、ワイヤ切れがいっそう生じやすくなることもわかった。更に、切断加工処理中、スラッジはローラの溝にもたまりやすく、ワイヤが巻き付けられているローラからワイヤが脱溝するなど現象が頻発し、切断精度が著しく低下するという問題のあることもわかった。これらの問題は、何れも、従来のワイヤソー技術によってシリコンやガラスのインゴットを切断する際には現れなかったものである。

【０００６】また、砥粒をスラリ中に浮遊させたタイプの遊離砥粒型ワイヤソーによれば、切断加工時に砥粒が転動するため、単位時間あたりの切削量（切断速度）の向上が難しいという問題もあった。特に希土類合金はシリコンやガラスに比べて硬く、粘り気があり、切断しにくい材料であるため、遊離砥粒型ワイヤソーを用いて希土類合金を切断した場合には切断速度がかなり遅くなる。

【０００７】特開平８－１２６９５３号公報は、固定砥粒を有するワイヤを用い、水をクーラントとしてシリコンインゴットを切断する技術を開示している。しかし、この技術を希土類合金の切断に用いると、希土類合金のスラッジは排出性が悪いため、遊離砥粒の場合と同様の問題が生じる。

【０００８】本発明は斯かる諸点に鑑みてなされたものであり、その主な目的は、ワイヤ切れを防止して長時間の連続運転を可能にするとともに、切断速度を向上させることができる希土類合金の切断方法を提供することにある。



【０００９】また、本発明の他の目的は、上記希土類合金の切断方法を用いた希土類合金磁石の製造方法、ならびに当該希土類合金磁石を備えたボイスコイルモータを提供することにある。

【００１０】

【課題を解決するための手段】本発明の希土類合金の切断方法は、砥粒を固着させたワイヤを用いる希土類合金の切断方法であって、前記ワイヤと前記希土類合金との間に、２５℃における表面張力が３３ｍＮ／ｍ～４９ｍＮ／ｍの範囲内にある水系切削液を供給しながら前記希土類合金を切断することを特徴とする。

【００１１】前記水系切削液として、グリコールを含むものを好適に用いることができる。

【００１２】あるいは、前記水系切削液として、合成潤滑剤を含むものを用いることもできる。

【００１３】前記水系切削液は消泡剤を含んでもよい。また、前記水系切削液はＰＨが９～１１であることが好ましい。前記水系切削液は防錆剤を含んでもよい。

【００１４】前記ワイヤとして、フェノール樹脂によって固着させた砥粒を含むものを好適に用いることができる。砥粒としては、ダイヤモンド砥粒が好適に用いられる。

【００１５】前記水系切削液の温度を制御する工程を包含することが好ましい。

【００１６】前記希土類合金を切断する際に生じた前記希土類合金のスラッジを含む水系切削液を回収する工程と、前記水系切削液の温度を制御する前に、前記回収された水系切削液からスラッジを除去する工程とをさらに包含することが好ましい。

【００１７】前記水系切削液の温度を制御する工程は、スラッジが除去された一部の水系切削液の温度を調節する工程と、前記温度が調節された一部の水系切削液と温度が調節されていない残りの水系切削液とを混合する工程とを包含し、前記混合された水系切削液を前記ワイヤと前記希土類合金との間に供給するようにしてもよい。

【００１８】前記希土類合金を切断する際に生じた前記希土類合金のスラッジを前記水系切削液内から磁力によって分離するようにしてもよい。

【００１９】前記スラッジを回収する領域において０．２７テスラ以上の磁力を示すマグネットセパレータを用いることが好ましい。

【００２０】前記の希土類合金の切断方法は、外周にリング状の複数の溝が所定のピッチで形成され、回転可能に支持された複数のローラと、前記ローラを回転させながら前記ローラの前記溝に巻き付けた前記ワイヤを走行させる駆動手段とを備えたワイヤソー装置を用いて、好適に実行することができる。

【００２１】前記ワイヤに対して、上方から下方に向かって前記希土類合金を降下させながら前記希土類合金を

切断することが好ましい。

【００２２】前記希土類合金を複数のブロックに分割した状態で保持し、前記水系切削液の供給の少なくとも一部を前記複数のブロックの間隙を介して行うようにしてもよい。あるいは、前記切削液の供給を、切削液槽の開口部から供給される前記切削液中に前記ワイヤを走行させることによって行ってもよい。

【００２３】本発明による希土類合金板の製造方法は、希土類合金のインゴットを作製する工程と、上述の希土類合金の切断方法を用いて前記希土類合金のインゴットから複数の希土類合金板を分離する工程とを包含することを特徴とする。

【００２４】本発明による希土類合金磁石の製造方法は、希土類磁石合金粉末から焼結体を作製する工程と、上述の希土類合金の切断方法を用いて前記焼結体から複数の希土類合金磁石を分離する工程とを包含することを特徴とする。

【００２５】本発明によるボイスコイルモータは、前記希土類合金磁石の製造方法によって作製された希土類合金磁石を備えていることを特徴とする。

【００２６】前記希土類合金磁石の厚さは、０．５～３．０ｍｍの範囲にあってもよい。

【００２７】

【発明の実施の形態】本願発明者は、切断速度を向上させる目的のため、砥粒を固着させたワイヤを用いて希土類合金を切断した。砥粒がワイヤに固定されることによって切削時における砥粒の転がりを阻止できるため、切断速度が向上する。この方法による場合、砥粒を浮遊させるためのスラリが不要になるが、スラッジを切削部から洗い流す（排出する）ためには、切削液を切断加工部分に十分に供給する必要がある。本発明者の実験によれば、切削液として水（水道水）を用いた場合、希土類合金のスラッジが切削溝内にたまりやすく、そのせいで切削抵抗が著しく増加し、ワイヤ切れが生じやすくなることがわかった。このような現象は、前述のように遊離砥粒型の場合にも見られたものである。しかし、砥粒を固着させたワイヤを用いる場合、切断対象である希土類合金から単位時間に削り取られるスラッジの量が多くなるため、切削抵抗の増大は、より大きな問題となる。

【００２８】また、切削液として水を用いて希土類合金を切断した場合、固定砥粒を有するワイヤの摩耗が激しく、ワイヤの切削能力が短時間の間に低下する結果、切断速度が大きく低下することがわかった。希土類合金は硬くて粘り気が高い材料であるため、切断時においてワイヤと希土類合金との間で生じる摩擦が大きい。切削液として水を用いて希土類合金を切断する場合は、この摩擦を十分に低減することができないものと考えられる。このことも、希土類合金よりも切断が容易であるシリコンやガラスのインゴットを切断する際には、大きな問題にはなっていなかった。

【００２９】また、凝集したスラッジがワイヤソー装置内の切削液循環パイプ内で切削液の循環を阻害すると、それによって切削液循環パイプが詰まるため、切削液の交換を頻繁に行わない限り長時間の連続運転を実施することが不可能になる。スラッジの沈殿・凝集は、希土類合金を構成する鉄および希土類元素の比重が大きいために生じると考えられる。ワイヤソーを用いてシリコンや石英ガラスのインゴットを切断した場合は、スラッジは切削液によって速やかに洗い流され、スラッジの沈殿・凝集はほとんど生じず、そのことに起因する大きな問題は今まで特に発生していなかった。

【００３０】本発明者は、切削液として水を用いる代わりに、所定範囲の表面張力を有する水系切削液を用いることによって、切削抵抗を低減できることを見出した。後述するように、水系切削液の２５℃における表面張力は３３ｍＮ／ｍ～４９ｍＮ／ｍの範囲内にあることが望ましい。上記の範囲内の表面張力を有する水系切削液は、水に比べて、ダイヤモンド系砥粒を含む切削端に対する浸透性（濡れ性またはなじみ）が優れるので、切削部（希土類合金と切削端とが接触し、希土類合金が切削される部分）に水系切削液が効率よく浸透するためと考えられる。なお、切削液の表面張力は、よく知られているデュヌイ表面張力計を用いて測定される。また、水系切削液は、水を主成分とするので、一般的に切削油（典型的に鉱物油を含む）に比べて比熱が大きいので、冷却効率に優れる。さらに、切削液の廃棄処理によって自然環境に悪影響を及ぼすことを防止することができる利点もある。

【００３１】２５℃の表面張力を用いて、本発明の切削方法で用いられる水系切削液を特定したが、実際に使用する際の水系切削液の温度は、２５℃に限られない。但し、本発明の効果を得るためには、１５℃～３５℃の範囲内に温度制御された水系切削液を用いることが好ましい。例えば、切削液を循環させて使用する場合、初期には室温程度の比較的低い温度で供給される切削液の温度は、ワイヤと希土類合金との間で発生する摩擦熱を切削液が吸収することによって段々と上昇する。切削液を循環させて使用するうちに、切削液の温度は約５０℃を上回り得る。よく知られているように、液体の表面張力は温度に依存するので、実際に使用する水系切削液の温度が上記の温度範囲からあまり外れると、水系切削液の表面張力が上記の数値範囲から外れた状態と良く似た状態となり、切削効率が低下する。

【００３２】水系切削液の表面張力は、添加する、グリコール（グリコール誘導体を含む）、界面活性剤の種類や量を調整することによって、上記の範囲内に容易に調整することができる。これらに代えて、いわゆる「シンセティック（Ｓｙｎｔｈｅｔｉｃ）」と呼ばれる合成潤滑剤を水に添加することによって、上記範囲の表面張力を得ることもできる。これらを混合して用いることもで

きる。

【００３３】切削液として水を用いた場合には、以下の理由で上述の不具合が発生したものと考えられる。

【００３４】ワイヤによって希土類合金に形成される切削溝の幅は狭い（例えば、０．３mm以下）ので、切削溝に直接切削液を供給することが困難であり、切削液はワイヤに対して供給され、ワイヤに付着させた状態で切削溝内に供給される。このような方法で供給される切削液のワイヤに対する濡れ性が低いと、ワイヤから脱離しやすくなり、十分な量が切削溝内に供給されなくなり、切削液の効果が低下する。さらに、切削液の切削端への浸透性も低下する。

【００３５】すなわち、切削溝内に十分な量の切削液が供給されず、切削端への浸透性が低いと、切削抵抗は増加し、切削効率が低下し、ワイヤ切れが発生する可能性が高くなり、さらには希土類磁石の切断面の加工精度が低下するという問題も生じる。また、スラッジの排出性も低下し、比重の大きい希土類合金のスラッジは、切削溝から排出されにくくなり、その結果、溝内にたまったスラッジによって切削抵抗が増加する。希土類合金のスラッジはシリコンなどのスラッジに比べて硬いため、スラッジが排出されない場合には切削抵抗が著しく増加することになる。また、ワイヤを十分に冷却することができず、ワイヤの温度が異常上昇し、ワイヤの異常摩耗や、砥粒（典型的にはダイヤモンド系砥粒）の異常脱粒が生じ、切削効率や加工精度が低下する。

【００３６】上記範囲の表面張力を有する水系切削液は、ワイヤ（および希土類合金）に対して適度な濡れ性を有し、狭い切削溝に十分に供給される。また、切削液を循環させて使用する場合において、切削液の温度を調整することによって、長時間にわたって連続運転を行ったときにも、切削液を所定範囲の温度に維持できるとともに、切削液の表面張力を常に所望の範囲内に制御することができる。これにより、切削抵抗の増加を防いで効率的に精度良く希土類合金を切断することが可能になる。なお、切削液の潤滑性や粘度（動粘度）も切削性能に影響するため、切削液の好ましい表面張力の範囲は、用いる切削液の種類によって多少異なり得る。

【００３７】なお、切削液の粘度は、スラッジの排出性に特に影響する。水系切削液の動粘度は、切削油に比べて一般に低く、グリコール系以外の水系切削液の動粘度は、温度によらずほぼ１mm$^2$／ｓであるが、グリコールを含む切削液の動粘度は比較的高く、且つ、温度依存性も大きい。動粘度が６７mm$^2$／ｓを超えると、上記範囲の表面張力を有していても、切削溝に十分に供給され難くなることがあるので、ワイヤと希土類合金との間に供給される切削液の動粘度は、６７mm$^2$／ｓ以下であることが好ましい。勿論この場合にも、切削液の温度は、１５℃から３５℃の範囲内にあることが好ましい。さらに、切削液の温度は、２０℃から２５℃の範囲内にあることが好ましい。

【００３８】また、水系切削液は、比較的粘度が低いので、切削によって生成したスラッジから磁石を用いて希土類合金屑を容易に分別することが可能で、水系切削液を再利用することができる。例えば、水系切削液を循環使用する場合、切削液の循環パイプ内での詰まりを防止するとともに、切削液の頻繁な交換をほとんど不要とし、連続運転時間を従来技術に比較して著しく改善することができる。また、水系切削液の廃棄処理によって自然環境に悪影響を及ぼすことを防止することができる。なお、希土類合金が水系切削液に曝される時間は、比較的短いので、その間の酸化によって希土類合金の特性が劣化することはない。

【００３９】ワイヤの走行速度は速い（例えば、数百メータ／分～数千メータ／分）ので、水系切削液が発泡し、冷却効率が低下することがある。消泡剤を含む水系切削液を用いることによって、水系切削液の発泡による冷却効率の低下を抑制することができる。さらに、ＰＨが９～１１の範囲内にある水系切削液を用いることによって、希土類合金の腐食を抑制することができる。また、防錆剤を含む水系切削液を用いることによって、希土類合金の酸化を抑制することができる。これらは、希土類合金の種類や加工条件等を考慮して、適宜調整すればよい。

【００４０】（実施形態）以下、本発明による希土類合金板の製造方法の実施形態を説明する。本実施形態では、希土類合金としてネオジム（Ｎｄ）、鉄（Ｆｅ）およびホウ素（Ｂ）を主成分とする三元系の化合物Ｎｄ－Ｆｅ－Ｂ、またはＮｄ－Ｆｅ－ＢのＮｄの一部をＤｙ（ジスプロシウム）で置換し、Ｆｅの一部をＣｏ（コバルト）で置換したものを用いる。Ｎｄ－Ｆｅ－Ｂは、最大エネルギー積が３２０ｋＪ／ｍ$^3$を超える強力なネオジム磁石材料として知られている。

【００４１】図１のフローチャートを参照しながら、Ｎｄ－Ｆｅ－Ｂのインゴットを作製する方法を簡単に説明する。なお、磁石材料としての希土類合金を作製する方法は、例えば米国特許第４，７７０，７２３号明細書に詳細に開示されている。

【００４２】まず、図１のステップＳ１で原料を所定の成分比に正確に秤量した後、ステップＳ２で真空またはアルゴンガス雰囲気の高周波溶解炉にて原料を溶解する。溶解した原料を水冷の鋳型に鋳込み、所定の組成の原料合金を形成する。ステップＳ３で原料合金を粉砕し、平均粒径３～４μm程度の微粉末を作製する。ステップＳ４で微粉末を金型に入れ、磁界中でプレス成形する。このとき必要に応じて微粉末を潤滑剤と混合してからプレス成形を行う。次に、ステップＳ５で約１０００～１２００℃程度の焼結工程を行えばネオジム磁石素材を作製することができる。この後、ステップＳ６で磁石の保磁力を向上させるために約６００℃での時効処理を

実行し、希土類合金インゴットの作製を完了する。インゴットのサイズは、例えば３０ｍｍ×５０ｍｍ×６０ｍｍである。

【００４３】ステップＳ７では希土類合金インゴットの切断加工を行い、インゴットから切断した複数の薄板（基板またはウェハと称される場合がある）を形成する。ステップＳ８以降の説明を行う前に、以下において希土類合金のインゴットを本発明によるワイヤソー技術によって切断加工する方法を詳細に説明する。

【００４４】図２（ａ）および（ｂ）を参照する。まず、上述の方法で作製した複数のインゴット２０を例えばエポキシ樹脂からなる接着剤２２にて相互に固着し、複数のブロック２４ａ～２４ｃとして組み立てた状態で鉄製のワークプレート２６に固定する。ワークプレート２６と各ブロック２４ａ～２４ｃとの間の固着もまた接着剤２２によって達成される。より詳細には、ワークプレート２６と各ブロック２４ａ～２４ｃとの間には、ダミーとして機能する炭素製ベースプレート２８が配置され、この炭素製ベースプレート２８も接着剤２２を介してワークプレート２６および各ブロック２４ａ～２４ｃに固着されている。炭素製ベースプレート２８は、ブロック２４ａ～２４ｃの切断加工が終了した後、ワークプレート２６の下降動作が停止するまでワイヤソーによる切断加工を受け、ワークプレート２６を保護するというダミーとしての役割を担っている。

【００４５】本実施形態では、図２（ａ）の矢印Ａで示される方向（以下「ワイヤ走行方向」と称する）に沿って計測した各ブロック２４ａ～２４ｃのサイズが１００ｍｍ程度になるように各ブロックの大きさを設計している。本実施形態では、ひとつのインゴット２０についてワイヤ走行方向に沿って計測したサイズが約５０ｍｍであるため、２つのインゴット２０をワイヤ走行方向に沿って配列したものを重ね合わせることによって、上記ブロック２４ａ～２４ｃの各々を構成するようにしている。

【００４６】ワークプレート２６に固定された複数のインゴット２０を全体として「ワーク」と称するが、このワークを複数のブロックに分割することによって、次のような利点が生まれる。

【００４７】一塊りのワークについて、ワイヤ走行方向サイズ（切削溝の長さ）が切削液の引き込み量を越えて大きくなりすぎると、ワークの切断加工部分のうち切削液供給が不十分になる領域が発生し、このことによってワイヤ断線の生じるおそれがある。しかし、本実施形態のワークは適当なサイズのブロック２４ａ～２４ｃに分割されているため、ブロック２４ａ～２４ｃの隙間に切削液を供給することが可能になり、切削液供給不足の問題を解消できる。また、これにより、砥粒間にたまったスラッジを洗い流すこともできるため、切断効率も向上する。

【００４８】ブロック２４ａ～２４ｃの隙間に切削液を供給するため、本実施形態では、２本の切削液供給パイプ２９をワークプレート２８の上部に配置しており、スリット状ノズル２９ａを介して切削液供給パイプ２９内から新鮮な切削液を下方向に噴射するようにしている。切削液供給パイプ２９は、後述する切削液供給タンクからスラッジを含まない新鮮な切削液またはスラッジの除去された切削液を受け取る。切削液供給パイプ２９は、例えば二重管式の構造を持ち、下方のスリット２９ａの幅は長手方向に変化し、均一な切削液供給を実現するように設計されている。

【００４９】本実施形態では上述のようにワークを複数のブロックに分割しているが、各ブロック２４ａ～２４ｃの各々についてのワイヤ走行方向サイズをどの程度の大きさに設定すべきかは、切削液の表面張力やワイヤ走行速度によっても変化する。また、各インゴット２０の大きさによって、ひとつのブロックを構成するインゴット２０の数や配置も変化する。これらを考慮して、適宜最適なサイズのブロックにワークを分割すればよい。また、本実施形態では、ワークプレート２６の上側に切削液供給パイプ２９を設けているがワークプレート２６の下側でブロック間に切削液を供給するようにしてもよい。

【００５０】次に、図３Ａおよび図３Ｂを参照しながら、本実施形態で好適に使用されるワイヤソー装置の主要部３０を説明する。このワイヤソー装置には、一本のワイヤ３２が何重にも巻き付けられる３つのメインローラ３４ａ～３４ｃが備えつけられている。このうち、二つのメインローラ３４ａおよび３４ｂは、ワイヤソー装置によって回動自在に支持されているが、モータなどの駆動手段には直接的に接続されておらず、従動ローラとして機能する。これに対して、メインローラ３４ｃは不図示の駆動源例えばモータに接続されており、この駆動源によって所望の回転力を受け、設定速度で回転することができる。メインローラ３４ｃはワイヤ３２を介して二つのメインローラ３４ａおよび３４ｂに回転力を伝達するため、駆動ローラとして機能する。

【００５１】ワイヤ３２は、メインローラ３４ａ～３４ｃの回転に応じて数キログラム重の張力を受けながら案内され、所定速度（例えば６００～１０００ｍ／分）で往復走行しながら不図示のリールから他の不図示のリールに巻きとられていく。

【００５２】メインローラ３４ａ～３４ｃの外周表面には、複数の溝が等間隔で形成されており、一本のワイヤ３２が多数の溝内にはめ込まれるようにして各ローラに巻き付けられる。ワイヤ３２の配列ピッチ（ワイヤ列の間隔）は、この溝のピッチによって規定される。本実施形態では、このピッチを約２．０ｍｍに設定している。このピッチは切断加工によって切り出すべき薄板の厚さに応じて設定されるため、適宜適切なピッチを持った多

溝ローラ３４ａ～３４ｃを選択して使用することになる。

【００５３】ワイヤ３２は、例えば硬鋼線（ピアノ線）から形成され、その太さは０．０６～０．２５ｍｍ程度のものが使用される。ワイヤの断面構成を図６に示す。図６からわかるように、本実施形態で用いるワイヤ芯線６１の表面には粒径が３０～６０μｍのダイヤモンド砥粒６２が樹脂膜６３によって固着されている。樹脂膜６３は例えばフェノール樹脂などから形成され、その膜厚は例えば３０～６０μｍである。固着された状態にある砥粒６２どうしの間隔は、砥粒６２の直径の約２～４倍であることが好ましい。また樹脂膜６３に代えて、Ｎｉ等の金属膜でダイヤモンド砥粒６２を固定することもできる。

【００５４】なお、ワイヤ芯線６１は、Ｎｉ－ＣｒやＦｅ－Ｎｉ等の合金、ＷやＭｏ等の高融点金属、またはナイロン繊維を束ねたものから形成されていても良い。また、砥粒の材料はダイヤモンドに限定されず、ＳｉＣ、Ｂ、Ｃ、ＣＢＮ(Cubic BoronNitride)等であってもよい。

【００５５】切断加工処理に際して、ワークは走行するワイヤ３２のうちメインローラ３４ａとメインローラ３４ｂとの間に張り渡された部分に押しあてられる。本実施形態では、切削液を少なくとも３カ所からワイヤ３２上に供給することができ、そのうち２カ所からの切削液供給は、ワークプレート２６の上部に配置したパイプ２９およびスリット状ノズル２９ａを用いブロックの隙間を利用して行う。残り一カ所からの切削液供給は、図３Ｂにおいてワークの左側からノズル３６を用いて行う。切削液の供給は、これらのノズル２９ａおよび３６に加えて、他のノズルを用い、例えば図３Ｂにおいてワークの右側の位置から付加的に行ってもよい。

【００５６】さらに、特に粘度の低い切削液を用いる場合や、ワイヤ３２の走行速度が速い（例えば１０００ｍ／分以上）場合のように、ワイヤ３２に切削液を供給し難い場合には、図３Ｂに示すように、ワイヤ３２を切削液槽３８開口部から溢れて供給される切削液中を走行させることによって、ワイヤ３２に切削液をより確実に供給することができる（例えば、特開平１１－１９８０２０号公報参照）。

【００５７】本実施形態では、ワークとワイヤとの間に、表面張力が３３ｍＮ／ｍ～４９ｍＮ／ｍの範囲内の水系切削液を供給する。ワークに形成される切削溝の幅は典型的には約０．３ｍｍ以下と非常に狭く、切削溝に切削液を直接的に供給することは困難である。このため、ワイヤに対して切削液を供給し、これをワイヤによって溝内に引き込ませ、その後、溝外へと排出させている。このようにして供給される表面張力が３３ｍＮ／ｍよりも低いか、あるいは４９ｍＮ／ｍよりも高いと、ワイヤに対する濡れ性が悪く、十分な量の切削液が溝内に供給されず、比重が大きい希土類合金から形成されるスラッジは切削溝から排出され難くなり、その結果、切削抵抗が上昇する。また、十分な量の切削液が切削溝内に供給されないと、ワイヤと希土類合金との間で十分な潤滑性が得られず（切れ味が低下する）、切断面の面粗度や寸法精度が悪くなる。また、切削端の摩擦係数が適正な範囲にコントロールされず、その結果、砥粒の異常摩耗が起こり、ワイヤの摩耗性が高くなるという問題も生じる。その結果、切断効率が大きく低下するとともに、ワイヤの寿命が短くなる。

【００５８】これに対し、上記範囲内の表面張力を有する水系切削液を使用すれば、十分な量の切削液が溝内に供給されるので、希土類合金の切削溝内で生じたスラッジ（すなわち、比重の大きい希土類合金粉末（例えば、ネオジム合金の比重は約７．５））は、速やかに切削溝の外部へ流れだし（高い排出効率）、切削加工領域から排除される。このため、切削溝内にたまったスラッジがワイヤの走行を強く妨げることもなく、切削抵抗増加によるワイヤ切れや切断効率低下の問題を解決できる。また、切削端における摩擦係数も適正な範囲にコントロールされる。さらに、水系切削液は、切削油に比べて比熱が高いので、冷却効率にも優れ、摩擦による温度の異常上昇を効率的に抑制・防止することができる。また、水系切削液は比較的粘性が低いので、走行するワイヤによってメインローラにまで運ばれるスラッジの量も低減され、メインローラ上の溝内にスラッジがたまるという現象も抑制できる。この結果、ワイヤ切れが防止され、また、ワーク切断終了後にワークからワイヤを簡単にはずすことができるという利点もある。

【００５９】水系切削液としては、例えば、グリコール系切削液（ユシロ化学工業株式会社製：ＷＬ－２）を用いることができる。用いるグリコールの種類や分子量によって、水への添加量を調整することによって、所望の表面張力の水系切削液を調製することができる。

【００６０】また、水に界面活性剤を添加した切削液を用いることもできる。界面活性剤としては、アニオン系として、脂肪酸石鹸やナフテン酸石鹸等の脂肪酸誘導体、又は長鎖アルコール硫酸エステルや動植物油の硫酸化油等の硫酸エステル型、又は石油スルホン酸塩等のスルホン酸型、非イオン系として、ポリオキシエチレンアルキルフェニルエーテルやポリオキシエチレンモノ脂肪酸エステル等のポリオキシエチレン系、ソルビタンモノ脂肪酸エステル等の多価アルコール系、又は脂肪酸ジエタノールアミド等のアルキロールアミド系を用いることができる。具体的には、ケミカルソリューションタイプのＪＰ－０４９７Ｎ（カストロール社製）を水に２重量％程度添加することによって、表面張力を好適な範囲内に調整することができる。

【００６１】さらに、水に合成潤滑剤を添加した切削液を用いることもできる。シンセティックタイプ合成潤滑

剤としては、シンセティック・ソリューションタイプ、シンセティック・エマルションタイプおよびシンセティックソリュブルタイプを用いることができ、そのなかでも、シンセティック・ソリューションタイプが好ましく、具体的には、シンタイロ９９５４（カストロール社製）や＃８７０（ユシロ化学工業社製）を挙げることができる。いずれも、水に２重量%程度添加することによって、表面張力を好適な範囲内に調整することができる。

【００６２】また、切削液に錆止め剤を含有させることで、希土類合金の腐食を防止することができる。ここで、ＰＨは９～１１とすることが好ましい。錆止め剤としては、有機系として、オレイン酸塩や安息香酸塩等のカルボン酸塩、又はトリエタノールアミン等のアミン類、無機系として、りん酸塩、ホウ酸塩、モリブデン酸塩、タングステン酸塩、又は炭酸塩を用いることができる。

【００６３】また、非鉄金属防食剤としては、例えばベンズトリアゾール等の窒素化合物を、防腐剤としては、ヘキサハイドロトリアジン等のホルムアルデヒド供与体を用いることができる。

【００６４】また消泡剤としては、シリコーンエマルジョンを用いることができる。消泡剤を含有させることで、切削液の泡立ちを少なくし、切削液の切削溝への浸透性が改善され、冷却効果が高まり、ワイヤ３２の温度の異常上昇や異常摩耗が起こりにくくなる。

【００６５】このような水系切削液は不水溶性切削液（油）に比べ環境を汚染し難い。また、水系切削液は、発煙、引火の危険性が少なく安全であり、オイルミストを発生させないことから、水系切削液を用いれば作業環境を改善することができる。さらに、スラッジを除去することが容易であるため、水系切削液は再使用（循環使用）に適した材料でもある。

【００６６】図３Ｂを参照する。ワークプレート２６はワークの切断加工処理に際し、不図示の駆動装置によって所定の速度（例えば０．５～１．０ｍｍ／分）で下方向へ矢印Ｄに沿って動かされ、ワークプレート２６に固定されたワークを、水平横方向（矢印Ａ方向）に走行するワイヤ３２に押しつける。ワークとワイヤ３２との間に充分な量の切削液を供給することによってワークとワイヤ３２との間からスラッジを排出し、それによってワークを連続的に切削することができる。ワークプレート２６の降下速度を速くすると、切断効率は向上するが、切削抵抗が上昇するためワイヤ３２の波打ち現象が発生し、ワーク切断面の平面度が悪くなるおそれがある。ワーク切断面の平面度劣化は、あとの工程での研磨作業に要する時間を増大させたり、不良品の発生確率を増加させる。従って、ワークの降下速度、つまりワークの切断速度を適切な範囲内に設定する必要が生じる。

【００６７】ワークの降下によって、一定ピッチで配列されたワイヤ３２がマルチワイヤソーとしてワークを研削し、それに伴って多数の加工溝（切削溝）をワークに同時形成しながらその溝深さを増大させ、切断加工を進行させることになる。加工溝が各インゴットを完全に横切ったときに、そのインゴットの切断加工が達成され、ワイヤ列のピッチおよびワイヤの太さによって決まる厚さの多数のウェハが同時に切り出される。全てのインゴット２０の切断が完了した後、前述の駆動装置によってワークプレート２６は矢印Ｄに沿って上昇させられる。その後、各ブロックがワークプレート２６から分離されるとともに、切断されたウェハが各ブロックから分離されることになる。

【００６８】本実施形態では、ワイヤ３２の上方からワークを降下させながら切断加工を実行するため、切断加工を受けたインゴット２０は接着剤によってなおもワークプレート２６に結合した状態のまま、ワークプレート２６ともに下降してゆく。このように切断加工を受けたインゴット２０はワイヤの下方に位置するため、ワークの切断加工済み部分がワーク本体から分離・脱落したとしても、その脱落部分がワイヤ３２と再度接触するおそれはない。そのため、切断加工済みの合金板は高い品質状態で次の工程に回されることになる。

【００６９】次に、図４を参照しながら、ワイヤソー装置４０の切削液循環システムの概略構成を説明する。図４に模式的に示すように、装置４０内にはワイヤソー装置の主要部３０に切削液を供給するとともに、加工により形成されたスラッジを含む使用済み切削液を回収するための切削液循環システムが設けられている。

【００７０】この装置４０の場合、ワークの切断加工に際して、切削液供給タンク４２から第１の循環パイプ４４を介して、図３Ａおよび図３Ｂに示すワークプレート２６上の切削液供給パイプ２９およびノズル３６、または図３Ｃの切削液槽３８に切削液が供給される。このとき、ポンプＰ１が用いられる。切断加工のために用いられた切削液は、加工部分およびその周辺から滴下し、下方に位置する回収ドレイン３７およびその下方に設けられている加工機ドレイン３７’によって受け取られるようになっている。切削液は回収ドレイン３７および加工機ドレイン３７’から第２の循環パイプ４６を介して分離漕５４に運ばれ、そこで、後述するマグネットセパレータ５０によるスラッジ分離処理を受けたのち回収タンク４８にためられる。このスラッジ分離処理によって切断加工前の状態に近い状態に戻った切削液は、第３の循環パイプ４９を介して切削液供給タンク４２に送られる。このときは中継ポンプＰ２が用いられる。第３の循環パイプ４９の途中にはフィルタＦが挿入されており、フィルタＦは、マグネットセパレータ５０によって除去されなかったスラッジを除去することができる。フィルタＦとしては袋状のバッグフィルタが好適に用いられる。

【００７１】なお、切削液供給タンク４２は、フィルタＦを透過し得た微細なスラッジを沈殿させることができる。このため、第１の循環パイプ４４を介して主要部３０に送られる切削液中に残存しているスラッジの量を更に低減することが可能である。このとき、マグネットセパレータ５０によって微細なスラッジは磁化されているので凝集し、沈殿しやすくなっている。

【００７２】このように本実施形態では、切削液の供給および回収を循環的に実行しながら、スラッジの分離除去（フィルタリング）を効率的に実行するため、切削液交換作業の間隔が著しく延び、切断加工処理を長時間にわたって連続的に続けることが可能になる。なお、切削液の表面張力を所望の範囲内に維持するために、適当な時間間隔で、水または新しい切削液を補給してもよい。この場合、定期的に切削液の表面張力を実測し、表面張力が設定範囲内から外れる場合に、随時水または新しい切削液を装置内（例えば、切削液供給タンク４２）に補給するようにしてもよい。このような切削液の部分的な補給は、切断加工処理を中断することなく行える点で切削油の全量的交換と大きく異なっている。

【００７３】次に、図５を参照しながらマグネットセパレータ５０を説明する。このマグネットセパレータ５０は、スラッジを含む使用済み切削液（ダーティ液）５２を貯えた分離槽５４から、磁力を用いてスラッジを分離することができる。分離槽５４には分離壁５４ａが設けられている。この分離壁５４ａは、大きなスラッジを分離槽５４に沈降させる機能を持つ。ダーティ液５２中に浮遊し、ダーティ液５２とともに分離壁５４ａを乗り越えることができた細かいスラッジは、以下に詳述する方法によって磁気的に分離されることになる。

【００７４】マグネットセパレータ５０は、内側に強力な磁石が配置されたドラム５６と、ドラム５６の外周面の一部に密着しながら回転する絞りローラ５７とを備えている。ドラム５６は固定軸を中心に回転可能に支持されながら、分離槽５４内で切削液５２に部分的に接触するように配置されている。絞りローラ５７は、耐油性ゴムなどから形成されており、ドラム５６の外周面に対してバネの付勢力によって圧接される。ドラム５６が不図示のモータによって矢印の方向に回転すると、その回転が絞りローラ５７に摩擦力を与え、絞りローラ５７を回転駆動させる。

【００７５】回転するドラム５６の外周面には、切削液５２中に浮遊するスラッジがドラム５６内の磁石によって吸着する。ドラム５６の外周面に吸着したスラッジはドラム５６の回転に伴って切削液５２内から取り除かれ、ドラム５６と絞りローラ５７との間を通過する。スラッジは、やがてスクレイパ５８によってドラム５６の表面から掻き取られ、スラッジボックス５９内に集められる。このようにしてスラッジが除去された切削液はドラム５６の長手方向における端部からパイプ６０によって回収タンク４８に運ばれる。このようなマグネットセパレータ５０として使用可能なスラッジ除去手段の構造は、例えば実公昭６３－２３９６２号公報に開示されている。のちに説明する発明者の実験によると、切削液中の希土類合金のスラッジをドラム５６の表面に引き寄せるには、切削液５２内におけるドラム５６の外周面（スラッジ回収面）での磁力を０．２７テスラ以上にすることが好ましく、０．３テスラ以上にすることが更に好ましい。粘度の低い水系切削液を使用したことによって、マグネットセパレータ５０による希土類合金スラッジの回収を容易にするという利点をも得ることができる。切削液５２中に形成された磁界中を移動するスラッジの受ける粘性抵抗が低減されるため、多くのスラッジを効率よく回収することが可能になるからである。

【００７６】このようなセパレータを用いて効率的にスラッジを除去すれば、循環使用される切削液に含まれるスラッジの濃度を低く維持することができ、切削液とともに切削端に供給されるスラッジを少なくすることができるので、ワーク切断面でワイヤの受ける切断負荷を長期間にわたって充分に小さいレベルに保つことができる。

【００７７】以下、図７および図８を参照しながら、温度調節機を備えた別形態の切削液循環システム７０の構成を説明する。なお、上記図４および図５に示した循環システムに対して同様の構成を有する部分については同様の参照符号を付している。以下には、上記図４および図５に示した循環システムとは異なる構成を有する部分について主に説明する。

【００７８】図７に示す切削液循環システム７０では、ワークの切断加工に際して、浄化装置７２から第１の循環パイプ７６を介して、ワイヤソー装置の主要部３０に切削液が供給される。一方、主要部３０に設けられた回収ドレイン３７および加工機ドレイン３７’によって受け取られたダーティ液は、第２の循環パイプ７８を介して浄化装置７２に運ばれ、そこで、前述のマグネットセパレータ５０およびバッグフィルタ８４によるスラッジ分離処理を受けたのち回収タンク４８（分離槽８２および温度調節槽９２）にためられる。

【００７９】主要部３０において、ワイヤと希土類磁石との間で発生する摩擦熱を吸収することによって、循環システム７０を循環する切削液の温度は全体的に上昇する。切削液の温度が上昇すると、切削液の表面張力に起因する切削液の切削溝への供給不足と、冷却効率の低下とにより、切断における切削抵抗が増加してしまう。これに対し、循環システム７０では、浄化装置７２に接続された温度調節機７４を用いて、循環使用される切削液の温度を所定の温度範囲内に維持することができる。温度調節機７４としては、熱交換器等を備えた公知の温度調節機（例えば特公平８－２５１２５号公報に記載の温度制御装置など）を使用することができ、好ましくは、

温度調節機７４は冷却機能と加熱機能との両方を備えている。

【００８０】温度調節機７４は、例えば、切削液の温度が所定値を超えて上昇した場合に作動するように制御されており、主要部３０に供給される切削液の温度を所定範囲内に制御することができる。このように切削液の温度調節を行えば、ワイヤと希土類磁石との間に供給される切削液の表面張力を適切な範囲内に維持し、切削抵抗を増加させることがないので、切削液の交換を行わずとも希土類磁石の切断を連続して行うことができる。

【００８１】次に、図８を参照しながら浄化装置７２の構成を説明する。この浄化装置７２は、前述のマグネットセパレータ５０および分離槽８２を備える分離部８０と、温度調節槽９２を備える温度調節部９０とから構成されている。分離槽８２と温度調節槽９２とは隔壁８８によって隔てられており、隔壁８８は、切削液が槽間を自由に移動することを阻止する。隔壁８８の上部において、連通部８８ａ（図８に示す形態においては、各槽８２および９２の側壁の高さよりも低い高さを有する隔壁部分上方の隙間）が形成されており、切削液は、連通部８８ａを通って槽間を移動することができる。すなわち、分離槽８２と温度調節槽９２とは、各槽の上部の位置においてのみ流体が移動できるように、連通可能に接続されている。

【００８２】分離部８０において、ワイヤソー装置から運ばれたダーティ液は、マグネットセパレータ５０およびバッグフィルタ８４に供給される。マグネットセパレータ５０は大量の切削液を短時間に処理する能力を有し、比較的大きいスラッジを除去するのに適している。一方、バッグフィルタは比較的小さいスラッジを除去するのに適している。各分離装置（マグネットセパレータ５０およびバッグフィルタ８４）の処理能力や、切削液に含まれるスラッジの大きさ、量などに応じて、各分離装置への切削液の供給割合を適切に設定すれば、スラッジを効率良く分離させることが可能である。マグネットセパレータ５０およびバッグフィルタ８４への切削液の供給割合は、例えば８：２に設定される。ただし、分離装置の形態はこれに限られず、例えば、マグネットセパレータ５０を出た切削液の一部をバッグフィルタ８４で濾過する形態であってもよい。

【００８３】マグネットセパレータ５０によってスラッジが除去された切削液は、ドラム５６の長手方向における端部からパイプ８５によって分離槽８２に運ばれる。また、バッグフィルタ８４によってスラッジが除去された切削液は、パイプ８６によって分離槽８２に運ばれる。分離槽８２の容積は、例えば約２００Ｌに設定されている。

【００８４】パイプ８５および８６の開口から分離槽８２に流れ込んだ切削液は、隔壁８８によって一時的に分離槽８２に滞留し、温度調節槽９２に直接に流れこむことがない。したがって、マグネットセパレータ５０やバッグフィルタ８４で除去しきれなかったスラッジを分離槽８２において沈降させることができる。その結果、分離槽８２における切削液の上澄み部分のみが隔壁８８を超えて温度調節槽９２に流入する。

【００８５】分離槽８２で沈降したスラッジは、スラッジ吸収ポンプ８７によってマグネットセパレータ５０に戻される。これにより、分離槽８２内のスラッジの量を低減させることができ、かつ、このようなスラッジを再度マグネットセパレータ５０によって分離させる機会を得ることができる。このようにすれば、浄化装置７２のスラッジ除去性能を向上させることができる。

【００８６】なお、切削液の液面近くにスラッジが舞い上がることを防止しつつスラッジ吸収ポンプ８７の吸入口の近傍においてスラッジを沈降させるために、図８に示すように隔壁８８に傾斜部を設けてスラッジを集めたり、パイプ８５および８６の開口の位置を設定したりすることが望ましい。

【００８７】分離槽８２おいて形成された切削液の上澄み部分は、連通部８８ａを通って温度調節槽９２に移動する。温度調節槽９２の容積は、例えば４００Ｌに設定されている。温度調節槽９２に供給される切削液は、スラッジをほとんど含んでいない。

【００８８】このようにして温度調節槽９２にためられた切削液は、ポンプＰ３を用いて温度調節機７４（図７参照）に送られ、温度が下げられた後、再び温度調節槽９２に戻される。切削液を温度調節機７４に送る前に、分離部８０においてスラッジの除去を行うようにしているので、温度調節機７４においてスラッジがパイプ内に溜まることなどによって熱交換効率が低下することがなく、切削液の温度調節を効果的に行うことができる。

【００８９】本実施形態では、温度調節槽９２内の切削液の温度が所定の温度以上になったときに、ポンプＰ３および温度調節機７４を作動させ、その後、温度調節槽９２内の切削液の温度が所定の温度以下になったときに、ポンプＰ３および温度調節機７４を停止させている。従って、温度調節機７４には、温度調節槽９２に収容された切削液の全てが送られるわけではなく、所定の期間において切削液の一部が送られる。温度調節されて戻された一部の切削液と温度調節槽９２内の残りの切削液とは、攪拌機９４によって混合（攪拌）され、これにより、温度調節槽９２内の切削液の温度が均一化される。このようにすれば、温度調節した切削液を直接ワイヤソー装置の主要部に送る場合に比べて、ワイヤソー装置の主要部に供給される切削液の温度が急激に変化することが防止される。ワイヤソー装置の主要部に安定した温度で切削液を供給することができれば、切削液の表面張力などが大きく変化しないため、ワイヤソー装置は安定した切削を行うことができる。このようにして、本実施形態では、温度調節機７４を効果的に動作させなが

ら、温度調節槽９２内の切削液の温度を所定の温度範囲に維持することができる。

【００９０】一方、室温などの影響によって切削液の温度が低下し、切削液の表面張力が所定の範囲を超えて大きくなる場合がある。この場合、切削液が切削溝に十分に供給され難くなり、スラッジの排出性が低下し、切断抵抗が増加する。また、マグネットセパレータによるスラッジ除去能力の低下も生じ得る。さらに、切削端での摩擦係数が上昇し、砥粒の摩耗が激しくなる。このようなときには、温度調節機７２を用いて切削液の温度を上昇させ、切削液の表面張力を低下させることが有利である。

【００９１】また、グリコールを含む切削液は、動粘度が比較的高く、且つ、動粘度の温度依存性も大きい。動粘度が６７ｍｍ$^2$／ｓを超えると、上記範囲の表面張力を有していても、切削溝に十分に供給され難くなることがあるので、ワイヤと希土類合金との間に供給される切削液の動粘度は、６７ｍｍ$^2$／ｓ以下であることが好ましい。従って、グリコールを含む切削液を用いる場合には、表面張力が上記範囲にあるとともに、動粘度が６７ｍｍ$^2$／ｓ以下となるように、温度を制御することが好ましい。

【００９２】温度調節槽９２において温度制御された切削液は、ポンプＰ４によってワイヤソー装置の主要部３０（図７）へと送られる。ワイヤと希土類磁石との間に供給される切削液の温度は、好ましくは１５℃～３５℃となるように制御され、さらに好ましくは２０℃～２５℃に制御される。

【００９３】上述の実施形態では、切削液の供給および回収を循環的に実行しながら、スラッジの分離除去を効率的に実行するとともに、切削液の温度制御を行うことによって切削液の表面張力を適切な範囲に維持する。このようにすれば、切削溝からスラッジを適切に排出し、切削抵抗を低いレベルに維持することによって、切断効率を高め、切断面の精度を高くすることができる。従って、切削液の交換作業の間隔が著しく延び、切断加工処理を長時間にわたって連続的に続けることが可能になる。

【００９４】次に、図９および図１０を参照しながら、グリコール含有水系切削液を用いた場合における、切断性能に対する表面張力の影響について説明する。

【００９５】図９は、後述する図１０に示す実験を行った試験機（評価機）１０の構成を示す。試験機１０は、外周面に切断用ワイヤ１２が巻回され、回転軸が駆動モータ（不図示）に接続された巻きドラム１０２と、巻きドラム１０２から、被切断物（ワーク）１４を切断する切断部１０４を介して再び巻きドラム１０２へとワイヤ１２を案内する複数のプーリ１０６と、切断部１０４において、ワイヤ１２に向かって被切断物１４を直線的に移動させる（押し当てる）ことができる移動装置１０８とを備えている。また、ワイヤ１２の経路の途中には、テンション調節装置１１０が設けられている。テンション調節装置１１０は、ワイヤ１２が巻き掛けられた可動プーリ１１２に外側への付勢力Ｆを与えることによってワイヤ１２に張力を付与し、これにより、ワイヤ１２の弛みを防止することができる。さらにテンション調節装置１１０は、ワーク１４の押し当てなどによってワイヤ１２に所定以上の張力が働く場合には、上記付勢力Ｆに対抗して可動プーリ１１２が内側に移動することできるように構成されている。これにより、ワイヤ１２に加えられる張力を緩和しながら、ワイヤ１２がワーク１４に対して与える応力を平衡に保つ（すなわち、ワーク１４に対して一定圧力でワイヤの押し当てを行う）ことができる。ワイヤ１２として、芯線径０．１８ｍｍφ、仕上がり径０．２４ｍｍφ、破断荷重７～８．５ｋｇｆ、砥粒径４０～６０μｍ、フェノール樹脂被膜厚さ３０μｍ～６０μｍを用いた。

【００９６】切断部１０４のワイヤ１２’の上方には、切削液供給ノズル１１４が設けられており、ノズル１１４からワイヤ１２’へ切削液が滴下または噴射される。ワイヤ１２’に供給された切削液は循環使用されずに廃棄されており、従ってワイヤ１２’に供給される切削液の温度は、ほぼ一定に保たれている。

【００９７】この試験機１０を用いて、グリコール含有水系切削液をノズル１１４からワイヤ１２’に滴下させ、切断性能を測定した。なお、巻きドラム１０２の回転方向を定期的に反転させることによって、ワイヤ１２’を線速２００ｍ／ｍｉｎで双方向移動させた。また、付勢力Ｆおよび移動装置１０８の移動速度を適切に設定することによって、ワイヤ１２’に対しワーク１４を定圧４Ｎで押し当てて、定圧荷重にて切断を行った。なお、ワーク１４は、ブロック状の希土類焼結磁石から形成している。

【００９８】切削液としては、表面張力の異なる種々のグリコール含有水系切削液（ユシロ化学工業株式会社製：ＷＬ－１～ＷＬ－５）を約２５℃の温度で用いた。用いた切削液の２５℃における表面張力は、３３．６ｍＮ／ｍ～４８．９ｍＮ／ｍである。また、切削油（ユシロ化学工業株式会社製：ＨＴ－９、２５℃の表面張力：２９．６ｍＮ／ｍ）を参照試料とした。

【００９９】図１０は、試験機１０を用いて得られた、切削液の表面張力［ｍＮ／ｍ］と、切れ味低下係数α［％／単位対数時間］および切断性能定数γ［％］との関係を示すグラフである。切断性能定数γは、切断初期における切断性能（切れ味）を示すパラメータであり、特にスラッジ排出性などに影響されるものと考えられる。切れ味低下係数αは、時間に関する切断性能の低下率（α＜０）を表すパラメータであり、特にワイヤの摩耗を示すものと考えられる。具体的は、切断性能定数γおよび切れ味低下係数αは、以下の式（１）を満足する

値である。

【０１００】Ｙ＝αｌｎ（ｔ）＋γ　　　（１）

式（１）において、ｔは切断時間（ただし３分を１単位とする）を表し、Ｙは切断性能比を表す。切断性能比Ｙは、上記切削油を用いた場合の初期切断性能を１００としたときの切断性能として定義する。切断性能は、ワイヤによって希土類合金に形成された切削溝の深さを測定することによって決定している。なお、式（１）から、切断性能定数γは３分後（ｔ＝１）の切断性能比（対切削油）を表し、切れ味低下係数αは対数時間（ｌｎ（ｔ））に対する切削性能の変化率を表していることがわかる。

【０１０１】図１０のグラフからわかるように、２５℃における表面張力が３３．６ｍＮ／ｍ～４８．９ｍＮ／ｍのグリコール含有水系切削液を用いた場合、切断性能定数γは１００［％］未満であり、上記切削油を用いた場合よりは切断性能が低い。しかし、各水溶性切削液の切断性能定数γは７５［％］を上回っており、この程度の切断性能が得られれば、比較的効率良く希土類合金の切断を行うことが可能である。また、上記範囲の表面張力を有するグリコール含有水系切削液を用いた場合、切れ味低下係数αは－１６．５［％／単位対数時間］以上であり、長時間連続して切断を行った場合にも切れ味がそれほど大きく低下しないことがわかる。この切れ味低下係数αの値は、切削水（水道水）を用いた場合の切れ味低下係数に比べれば十分に良好な値であった。

【０１０２】このようにグリコール含有の水系切削液を用いる場合、特定の切削油を用いる場合に比べ、切削効率は悪くなるが、その反面、オイルミストなどが発生しないため作業性が良くなるという利点が得られる。また、水系切削液は環境を汚染し難く、この点では切削油よりも水系切削液を用いるほうが望ましい。また、水系切削液からはスラッジを除去することが比較的容易であるため、切削液を循環して使用する場合には、水系切削液は切削油よりも好適な材料であり得る。

【０１０３】上述の結果および種々検討した結果から、２５℃における表面張力が約３３ｍＮ／ｍ～約４９ｍＮ／ｍの水系切削液を用いることが好ましい。特に、２５℃での表面張力が３５ｍＮ／ｍ～４５ｍＮ／ｍの水系切削液（例えば、ユシロ化学工業株式会社製：ＷＬ－２）を用いることが好ましい。このような水系切削液を用いれば、環境汚染などを引き起こすことなく、効率良く希土類合金の切断を行うことが可能である。

【０１０４】図１１は、マグネットセパレータのスラッジ回収面（スラッジ回収領域）における磁力とワーク切断面の平面度との関係、およびマグネットセパレータのスラッジ回収面（スラッジ回収領域）における磁力とスラッジ排出量（切削液から取り除かれるスラッジの１時間あたりの量）との関係を示している。なお、図１１に示すデータは、１ｋｇ／時間のスラッジがワーク切断面から切削液中に取り込まれる条件のもとで得られた。このときの磁力（表面磁束密度）は、ガウスメータおよびプローブ（ともにベル社製）を用い、プローブをスラッジ回収面に接触させて測定した。

【０１０５】図１１からわかるようにマグネットセパレータの磁力が増加すると、それに伴ってスラッジ排出量が増加し、ワーク切断面の平面度が向上してゆく。マグネットセパレータによる切削液からのスラッジ排出量が少ない場合、スラッジの回収分離が充分に達成されず、スラッジ濃度が上昇する。このことは、ワイヤによる加工が行われている部分に供給される切削液中のスラッジ濃度を高めることにつながる。その結果、ワイヤに対する切削抵抗が増加し、ワイヤがたわむために、加工面の平坦度が低下すると考えられる。なお、マグネットセパレータによって希土類合金スラッジを適切に除去すれば、平面度が改善する以外にも、ワイヤ切削液の全量交換を実行しなくても長期間の連続運転が可能になるという効果が得られる。

【０１０６】ワーク切断面の平面度が１００μｍを超えると、あとの研磨工程に要する時間を考慮した場合の全体としての作業効率が低下するため、平面度は１５μｍ以下になることが好ましく、磁力も加工面の平面度が１５μｍ以下になるように調整されることが好ましい。そのためには、マグネットセパレータのドラム表面における磁力を０．２７テスラ以上に設定することが好ましく、０．３０テスラ以上にすることが更に好ましい。

【０１０７】再び、図１を参照する。上記方法を用いて切断加工した希土類合金板のそれぞれに対して研磨による仕上げ加工を行い、寸法と形状を整えた後、長期的な信頼性を向上させるため、ステップＳ８で合金板に表面処理を施す。ステップＳ９で着磁工程を実行した後、検査工程を経てネオジム永久磁石が完成する。

【０１０８】（実施例１）図７に示したワイヤソー装置を利用して、希土類合金の切断を行った。切削液としては、ユシロ化学工業株式会社製のグリコール含有水系切削液（ＷＬ－２）を使用した。温度調節機としては、関東精機株式会社製の自動温度調節機（ＫＴＣ－３Ｂ）を用いた。この装置は、冷却と加熱との両方の機能を有している。

【０１０９】また、切断用ワイヤとしては、芯線径：０．１８ｍｍ、フェノール樹脂の厚さ：２０μｍ、砥粒材質：ダイヤモンド、砥粒径：４０～６０μｍ、平均砥粒間隔：１００μｍのワイヤを用いた。このワイヤを線速８００ｍ／ｍｉｎで往復走行させ、新線供給量：２ｍ／ｍｉｎ、ワイヤテンション：３０Ｎの条件で装置を動作させた。被切削物としては、２０ｍｍ×４０ｍｍ×６０ｍｍの希土類合金を７段積みして接着し、これを４０ｍｍ／ｍｉｎの降下速度でワイヤに接触させた。上記条件の下で、温度調節機を稼動させ、切削油の温度を２５℃～２８℃の範囲に維持しながら希土類合金の切断を実

行した。

【０１１０】希土類合金を１８０mmまで切り込み、切断面を観察したところ、面精度Ｒａは０．８μm以下、Ｒｍａｘは７μm以下であり、平滑な面が形成された。切断された希土類合金は、ボイスコイル用モータに使用される磁石として要求される品質を満たしていた。また、切断中、ワイヤのたわみ量は略一定に維持され、切削抵抗の増加はなかった。

【０１１１】（比較例１）温度調節機を稼動しないことを除いて、上記実施例１と同様にして希土類合金の切断を行った。グリコール含有水系切削液の温度は当初２０℃であったが、切断が進むに連れて上昇し、５０℃以上に達した。

【０１１２】希土類合金を１８０mmまで切り込み、切断面を観察したところ、後に切断した部分ほど面精度が低下しており、切断面の面精度Ｒａは１．５μm以上、Ｒｍａｘは１５μm以上であり、凹凸が大きい面が形成された。切断された希土類合金は、ボイスコイル用モータに使用する磁石として要求される品質を満たしていなかった。また、切断中、ワイヤのたわみ量は徐々に増加し、切削抵抗の増加が認められた。

【０１１３】以上説明してきたように、上記希土類合金板品の製造方法によれば、以下に示すような数多くの有利な効果が得られる。

【０１１４】１．ワーク切断面からの切削液の排出効率が向上するため、ワイヤの受ける切削抵抗が低減され、長時間の連続切断作業が可能になる。

【０１１５】２．ワーク切断面の平面度を向上させることが可能になる。このため、製品の製造歩留まりが改善される。

【０１１６】３．希土類合金に対するワイヤソー切断の効率が最適化される。

【０１１７】４．切削液中のスラッジを効率的に除去できるため、切削液の交換を頻繁に実施しなくとも、ワーク切断面で受けるワイヤの切断負荷を低減し、それによって切断速度を向上させることが可能になる。

【０１１８】５．ワークの崩れが生じても、ワイヤとの接触によって製品の品質が劣化することが防止される。

【０１１９】なお、希土類合金板の製造方法について本発明の実施形態を説明してきたが、本発明はこれに限定されるものではない。例えば、板状以外の加工形状をもつ希土類合金製品・部品を作製するために、本発明の切断方法を好適に用いることができる。

【０１２０】また、被加工対象して、Ｎｄ－Ｆｅ－Ｂの希土類合金磁石材料を用いた実施形態を説明したが、切削抵抗が大きく、スラッジが凝集しやすいという性質は希土類合金全体に共通するため、本発明は他の希土類合金を被加工物として用いても上記実施形態について述べた効果と同様の効果を得ることができる。

【０１２１】上述の方法を用いて作製した希土類合金磁石は、外周刃を用いて希土類合金インゴットを切断する場合に比較して切断代が少なく、薄型の磁石（例えば、厚さ０．５～３．０mm）を製造するのに適している。近年、ボイスコイルモータに使用される希土類磁石は益々薄くなってきているため、本発明の方法を用いて製造した上記の薄い希土類合金磁石をボイスコイルモータに取り付ければ、高い性能を持つ小型ボイスコイルモータを提供することができる。

【０１２２】

【発明の効果】本発明によれば、希土類合金に対してワイヤソーによる切断加工を実行しようとする場合においても、ワイヤ切れが防止され、必要な切削液の交換回数も著しく低減される結果、長時間の連続運転が可能になる。

【図面の簡単な説明】

【図１】Ｎｄ－Ｆｅ－Ｂ永久磁石の作製手順を示すフローチャートである。

【図２】（ａ）はワークプレートに固定されたインゴットブロックを示す正面図であり、（ｂ）はその側面図である。

【図３Ａ】本発明の実施形態で好適に使用されるワイヤソー装置の主要部を示す斜視図である。

【図３Ｂ】本発明の実施形態で好適に使用される前記ワイヤソー装置の主要部を示す正面図である。

【図３Ｃ】本発明の実施形態で好適に使用される他のワイヤソー装置の主要部を示す正面図である。

【図４】前記ワイヤソー装置の切削液循環システムを示す概略構成図である。

【図５】前記ワイヤソー装置に備えつけられたマグネットセパレータ装置を示す斜視図である。

【図６】ワイヤの断面図である。

【図７】図４とは別形態のワイヤソー装置の切削液循環システムを示す概略構成図である。

【図８】図７に示す循環システムに備え付けられた浄化装置を示す斜視図である。

【図９】グリコール含有水系切削液のと切断性能との関係を調べるために用いた試験機である。

【図１０】グリコール含有水系切削液のと切断性能との関係を示すグラフである。

【図１１】マグネットセパレータの磁力とワーク切断面の平面度との関係を示すグラフである。

【符号の説明】

２０　希土類合金のインゴット

２２　接着剤

２４ａ～２４ｃ　インゴットのブロック（ワークブロック）

２６　ワークプレート

２８　炭素製ベースプレート

２９　切削液供給パイプ

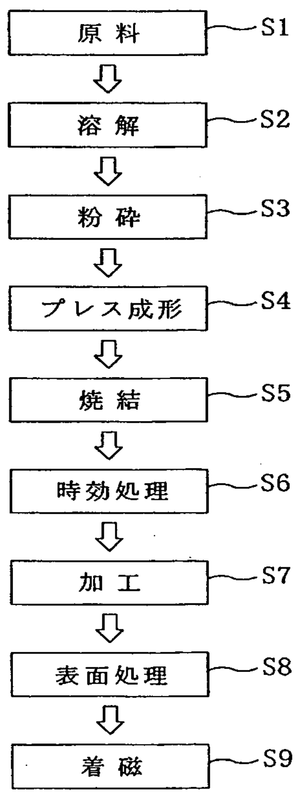
２９ａ　スリット状ノズル

３０　ワイヤソー装置の主要部
３２　ワイヤ
３４ａ～３４ｃ　メインローラ（多溝ローラ）
３６　ノズル
３７　スラリの回収ドレイン
３７’　加工機ドレイン
３８　切削液槽
４０　ワイヤソー装置
４２　切削液供給タンク
４４　第１の循環パイプ
４６　第２の循環パイプ

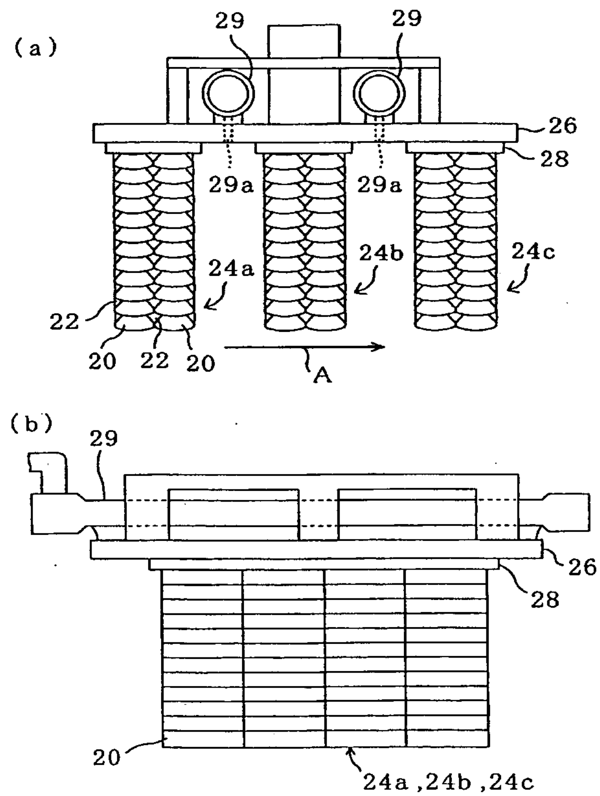


４８　切削液回収タンク
４９　第３の循環パイプ
５０　マグネットセパレータ
５２　スラッジを含む使用済み切削液（ダーティ液）
５４　分離漕
５４ａ　分離漕に設けられた開口部
５６　ドラム
５７　絞りローラ
５８　スクレイパ
５９　スラッジボックス

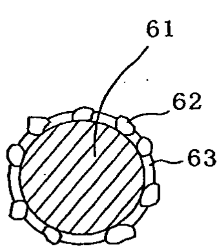
【図１】



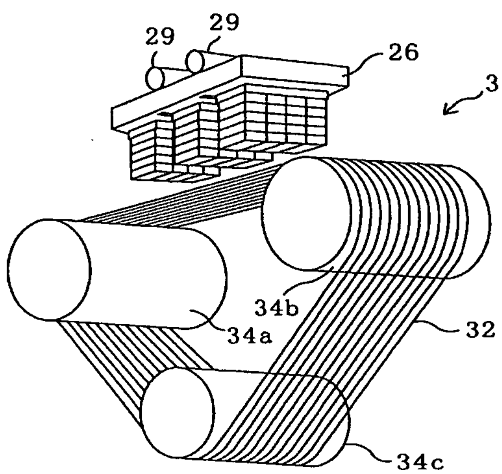

【図２】



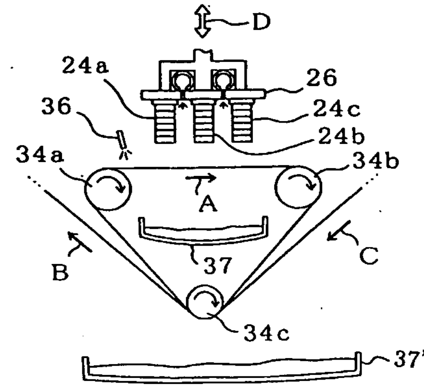

【図６】



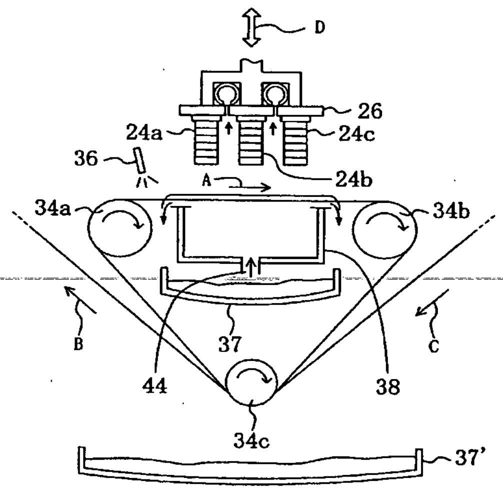
【図３Ａ】



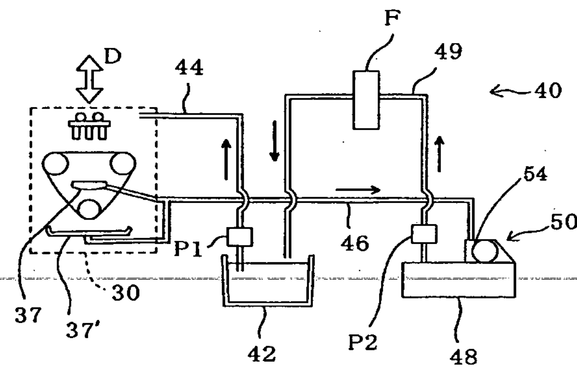

【図３Ｂ】



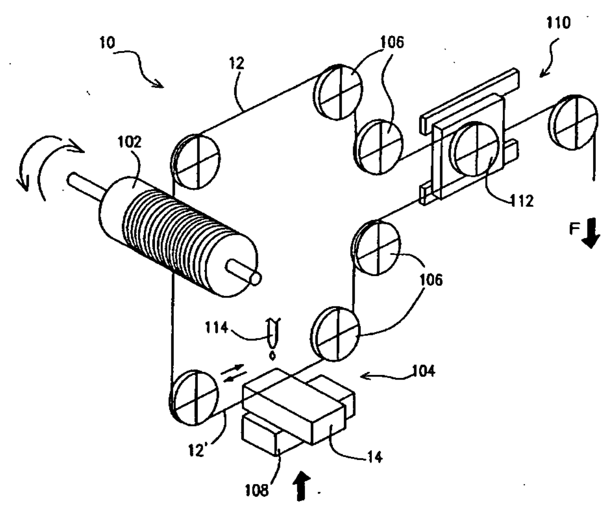

【図３Ｃ】



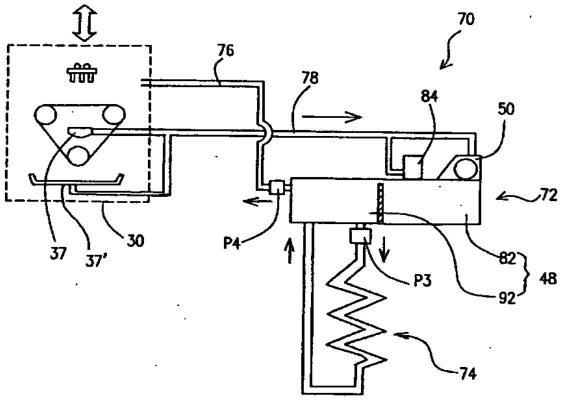

【図４】



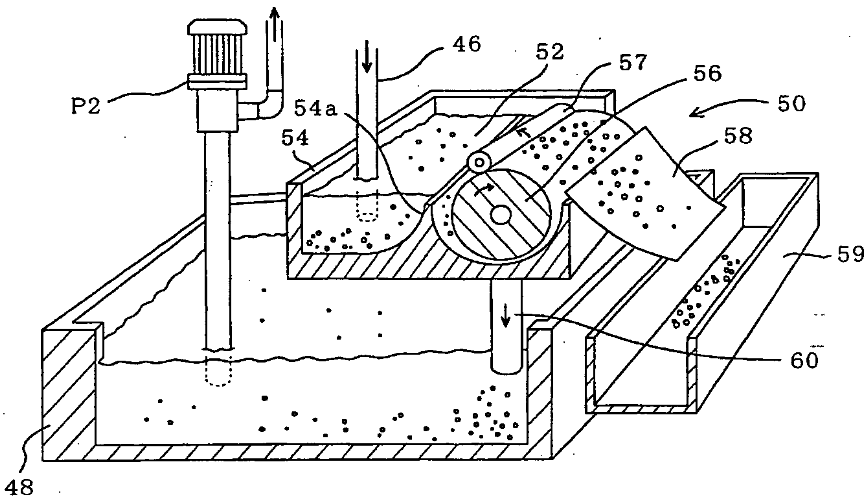

【図９】



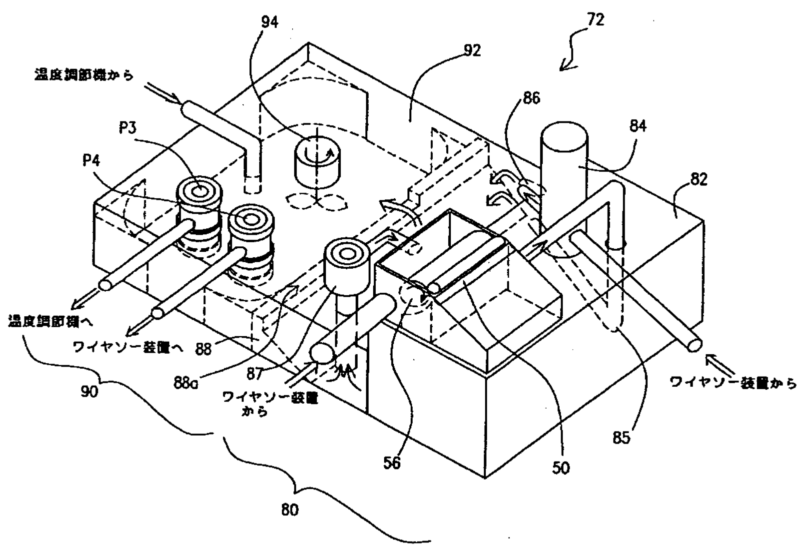

【図７】



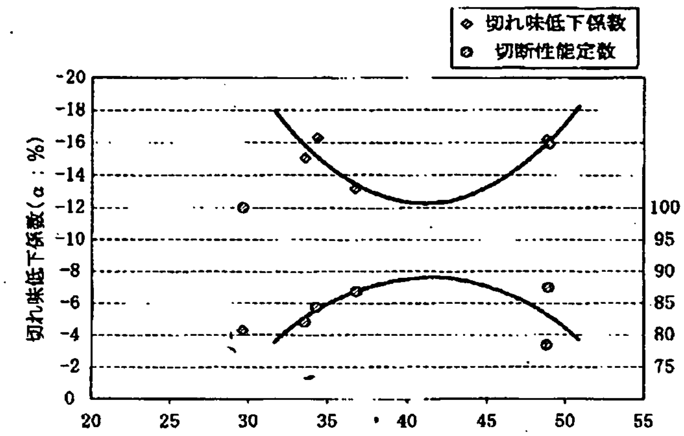
【図５】


P2
46
52
57
56
50
54a
54
58
59
60
48

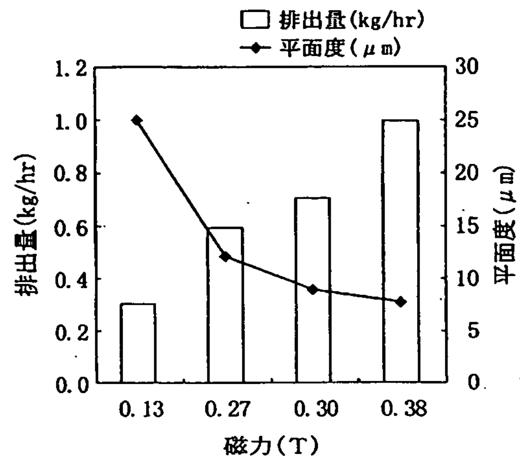
【図８】


94
92
72
温度調節機から
P3
P4
86
84
82
温度調節機へ
ワイヤソー装置へ
88
88a
87
ワイヤソー装置から
90
56
50
85
ワイヤソー装置から
80

【図１０】




【図１１】




フロントページの続き

Ｆターム(参考)　3C047 FF06 FF09 GG00
3C058 AA05 AC04 CA04 CB03 DA03
3C069 AA01 BA06 BB01 BB02 DA06
DA07
5E062 CC04 CD04

---

## CLAIMS

---

[Claim(s)]
[Claim 1] Cutting process of the rare earth alloy characterized by cutting said rare earth alloy, supplying the drainage system cutting fluid which is the cutting process of the rare earth alloy using the wire which made the abrasive grain fix, and has the surface tension in 25 degrees C within the limits of 33 mN/m - 49 mN/m between said wires and said rare earth alloys.
[Claim 2] Said drainage system cutting fluid is the cutting process containing a glycol of a rare earth alloy according to claim 1.
[Claim 3] Said drainage system cutting fluid is the cutting process containing synthetic lubricant of a rare earth alloy according to claim 1.
[Claim 4] Said drainage system cutting fluid is the cutting process of a rare earth alloy given in either containing a defoaming agent of claims 1-3.
[Claim 5] Said drainage system cutting fluid is the cutting process of a rare earth alloy given in either of claims 1-4 whose PHs are 9-11.
[Claim 6] Said drainage system cutting fluid is the cutting process of a rare earth alloy given in either containing a rusr-proofer of claims 1-5.
[Claim 7] Said wire is the cutting process of a rare earth alloy given in either containing the abrasive grain made to fix with phenol resin of claims 1-6.
[Claim 8] Cutting process of a rare earth alloy given in any of claims 1-7 which include the process which controls the temperature of said drainage system cutting fluid they are.
[Claim 9] Cutting process of the rare earth alloy according to claim 9 which includes the process which collects the drainage system cutting fluid containing the sludge of said rare earth alloy produced when cutting said rare earth alloy, and the process which removes a sludge from said collected drainage system cutting fluid before controlling the temperature of said drainage system cutting fluid.
[Claim 10] The process which controls the temperature of said drainage system cutting

fluid is the cutting process the rare earth alloy according laim 9 characterized by to include the process which mixes the process which adjusts the temperature of some drainage system cutting fluid from which the sludge was removed, and some [ by which said temperature was adjusted ] drainage system cutting fluid and the remaining drainage system cutting fluid with which temperature is not adjusted, and to supply said mixed drainage system cutting fluid between said wires and said rare earth alloys.
[Claim 11] Cutting process of a rare earth alloy given in any of claims 1-10 characterized by separating the sludge of said rare earth alloy produced when cutting said rare earth alloy by magnetism from the inside of said drainage system cutting fluid they are.
[Claim 12] Cutting process of the rare earth alloy according to claim 11 characterized by using the magnetic separator which shows the magnetism of 0.27 teslas or more in the field which collects said sludges.
[Claim 13] Cutting process of a rare earth alloy given in any of claims 1-12 characterized by using wire saw equipment equipped with two or more rollers which two or more ring-like slots were formed in the periphery in the predetermined pitch, and were supported pivotable, and the driving means which makes it run said wire twisted around said slot of said roller while rotating said roller they are.
[Claim 14] Cutting process of the rare earth alloy according to claim 13 characterized by cutting said rare earth alloy, going caudad from the upper part and dropping said rare earth alloy to said wire.
[Claim 15] Cutting process of the rare earth alloy according to claim 14 characterized by holding where said rare earth alloy is divided into two or more blocks, and performing a part of supply [ at least ] of said drainage system cutting fluid through the gap of a block of said plurality.
[Claim 16] Cutting process of the rare earth alloy according to claim 14 characterized by carrying out by making it run said wire in said cutting fluid to which supply of said cutting fluid is supplied from opening of a cutting fluid tub.
[Claim 17] The manufacture approach of the rare earth alloy plate characterized by including the process which produces the ingot of a rare earth alloy, and the process which separates two or more rare earth alloy plates from the ingot of said rare earth alloy using the cutting process of a rare earth alloy given in any of claims 1-16 they are.
[Claim 18] The manufacture approach of the rare earth alloy magnet characterized by including the process which produces a sintered compact from rare earth magnet alloy powder, and the process which separates two or more rare earth alloy magnets from said sintered compact using the cutting process of a rare earth alloy given in any of claims 1-16 they are.
[Claim 19] The voice coil motor characterized by having the rare earth alloy magnet produced by the manufacture approach of a rare earth alloy magnet according to claim

18.
[Claim 20] The voice coil motor according to claim 19 characterized by being in the range whose thickness of said rare earth alloy magnet is 0.5-3.0mm.

---

[Translation done.]

## DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the cutting process and cutting equipment of a rare earth alloy. It is related with the approach of cutting a rare earth alloy using the wire which made the detail fixing superabrasives, such as a diamond abrasive grain, more.
[0002]
[Description of the Prior Art] Conventionally, in order to cut down many wafers from the ingot of silicon, the technique of using a wire saw and cutting an ingot is developed, for example, it is indicated by JP,6-8234,A. According to such a technique, cutting / cutting processing of an ingot is performed supplying the slurry which contains a grinding abrasive grain to the multi-wire it runs, and it becomes possible to cut down the wafer of fixed thickness to several multi-sheet coincidence.
[0003] The technique which slices an ingot from the former as an approach of cutting the ingot of a rare earth alloy, on the other hand using the slicing blade rotated, for example is known. However, according to the approach of cutting with a slicing blade, since it is large compared with a wire gage, the chipping allowance of thickness of a cutting cutting edge surely increases, and it cannot aim at a deployment of a resource.
[0004] The rare earth alloy is suitably used as for example, a magnet ingredient. Since a magnetic application is diversified and it is widely used also for various kinds of electronic equipment, if the wafer of predetermined thickness is producible from the ingot of a rare earth alloy to several multi-sheet coincidence in few chipping allowances with a wire saw, the manufacturing cost of a rare earth magnet will be reduced sharply.
[0005]
[Problem(s) to be Solved by the Invention] However, there is still no report that the rare earth alloy was cut using the practical wire saw technique. If it is going to perform

cutting processing processing by the loose grain mold wire saw to the ingot of a rare earth alloy, as a result of getting a slurry circulation pipe blocked for a short time extremely for the fines and grinding waste (as ** or a sludge) generated by wire saw processing according to the experiment of artificers, the slurry was no longer supplied on the wire and it turned out that a wire piece will arise. Since it must stop having to interrupt processing by the wire saw at every slurry exchange when the whole slurry is exchanged completely every several hours, in order to avoid this problem, it is not suitable for mass production and utilization becomes impossible. Moreover, the bank and because [ its ] it became empty, cutting force increased also to cutting Mizouchi remarkably, and the sludge also understood much more becoming easy to produce a wire piece. Furthermore, it also turned out during cutting processing processing that phenomena -- a wire carries out a deslot -- occur frequently also into the slot on the roller from the roller with which the bank and the wire to like are twisted, and, as for a sludge, there is a problem that cutting precision falls remarkably. In case each of these problems cuts the ingot of silicon or glass with the conventional wire saw technique, they does not appear.

[0006] Moreover, according to the loose grain mold wire saw of a type which made the abrasive grain float in a slurry, since an abrasive grain rolled at the time of cutting processing, there was also a problem that improvement in the amount of cutting per unit time amount (cutting speed) was difficult. Especially, a rare earth alloy is hard compared with silicon or glass, and it is sticky, and since it is the ingredient which is hard to cut, when a rare earth alloy is cut using a loose grain mold wire saw, cutting speed becomes quite slow.

[0007] JP,8-126953,A is indicating the technique of cutting a silicon ingot by making water into a coolant, using the wire which has bonded abrasive. However, if this technique is used for cutting of a rare earth alloy, since eccritic is bad, the same problem as the case where it is a loose grain will produce the sludge of a rare earth alloy.

[0008] This invention is made in view of these many points, and the main purpose is to offer the cutting process of the rare earth alloy which can raise cutting speed while it prevents a wire piece and makes prolonged continuous running possible.

[0009] Moreover, other purposes of this invention are to offer the voice coil motor equipped with the manufacture approach of a rare earth alloy magnet of having used the cutting process of the above-mentioned rare earth alloy, and the rare earth alloy magnet concerned.

[0010]

[Means for Solving the Problem] The cutting process of the rare earth alloy of this invention is the cutting process of the rare earth alloy using the wire which made the abrasive grain fix, and while the surface tension in 25 degrees C supplies the drainage system cutting fluid which is within the limits of 33 mN/m - 49 mN/m between said wires

THIS PAGE BLANK (USPTO)

and said rare earth alloys, has characterized by cutting said rare earth alloy.
[0011] As said drainage system cutting fluid, the thing containing a glycol can be used suitably.
[0012] Or the thing containing synthetic lubricant can also be used as said drainage system cutting fluid.
[0013] Said drainage system cutting fluid may also contain a defoaming agent. Moreover, as for said drainage system cutting fluid, it is desirable that PHs are 9-11. Said drainage system cutting fluid may also contain a rusr-proofer.
[0014] What contains the abrasive grain made to fix with phenol resin as said wire can be used suitably. As an abrasive grain, a diamond abrasive grain is used suitably.
[0015] It is desirable to include the process which controls the temperature of said drainage system cutting fluid.
[0016] It is desirable to include further the process which collects the drainage system cutting fluid containing the sludge of said rare earth alloy produced when cutting said rare earth alloy, and the process which removes a sludge from said collected drainage system cutting fluid before controlling the temperature of said drainage system cutting fluid.
[0017] The process which controls the temperature of said drainage system cutting fluid includes the process which mixes the process which adjusts the temperature of some drainage system cutting fluid from which the sludge was removed, and some [ by which said temperature was adjusted ] drainage system cutting fluid and the remaining drainage system cutting fluid with which temperature is not adjusted, and you may make it supply said mixed drainage system cutting fluid between said wires and said rare earth alloys.
[0018] You may make it magnetism separate the sludge of said rare earth alloy produced when cutting said rare earth alloy from the inside of said drainage system cutting fluid.
[0019] It is desirable to use the magnetic separator which shows the magnetism of 0.27 teslas or more in the field which collects said sludges.
[0020] Two or more ring-like slots are formed in a periphery in a predetermined pitch, and cutting process of the aforementioned rare earth alloy can be suitably performed using wire saw equipment equipped with two or more rollers supported pivotable and the driving means which makes it run said wire twisted around said slot of said roller while rotating said roller.
[0021] It is desirable to cut said rare earth alloy, going caudad from the upper part and dropping said rare earth alloy to said wire.
[0022] It holds, where said rare earth alloy is divided into two or more blocks, and it may be made to perform a part of supply [ at least ] of said drainage system cutting fluid through the gap of a block of said plurality. Or you may carry out by making it run said wire in said cutting fluid to which supply of said cutting fluid is supplied from opening of

a cutting fluid tub.
[0023] The manufacture approach of the rare earth alloy plate by this invention is characterized by including the process which produces the ingot of a rare earth alloy, and the process which separates two or more rare earth alloy plates from the ingot of said rare earth alloy using the cutting process of an above-mentioned rare earth alloy.
[0024] The manufacture approach of the rare earth alloy magnet by this invention is characterized by including the process which produces a sintered compact from rare earth magnet alloy powder, and the process which separates two or more rare earth alloy magnets from said sintered compact using the cutting process of an above-mentioned rare earth alloy.
[0025] The voice coil motor by this invention is characterized by having the rare earth alloy magnet produced by the manufacture approach of said rare earth alloy magnet.
[0026] The thickness of said rare earth alloy magnet may be in the range of 0.5-3.0mm.
[0027]
[Embodiment of the Invention] The invention-in-this-application person cut the rare earth alloy using the wire which made the abrasive grain fix for the purpose which raises cutting speed. Since ** of the abrasive grain at the time of cutting can prevent ** by fixing an abrasive grain to a wire, cutting speed improves. When based on this approach, the slurry for making an abrasive grain float becomes unnecessary, but in order to flush a sludge from the cutting section (it discharges), it is necessary to fully supply cutting fluid to a cutting processing part. According to the experiment of this invention person, when water (tap water) was used as cutting fluid, it turned out that cutting force increases [ the sludge of a rare earth alloy ] to cutting Mizouchi remarkably because [ its ] it becomes empty, the bank and, and it becomes easy to produce a wire piece. Also in the case of a loose grain mold, such a phenomenon is seen as mentioned above. However, since the amount of the sludge shaved [ rare earth alloy / which is a candidate for cutting ] by unit time amount increases when using the wire which made the abrasive grain fix, increase of cutting force poses a bigger problem.
[0028] Moreover, when a rare earth alloy was cut using water as cutting fluid, the wear of a wire which has bonded abrasive was intense, and as a result of the cutting capacity of a wire declining between short time, it turned out that cutting speed falls greatly. Since a rare earth alloy is an ingredient with stickiness it is hard and high, its friction produced between a wire and a rare earth alloy at the time of cutting is large. When cutting a rare earth alloy, using water as cutting fluid, it is thought that this friction cannot fully be reduced. When this also cut the ingot of silicon with easier cutting than a rare earth alloy, or glass, it had not become a big problem, either.
[0029] Moreover, if the condensed sludge checks circulation of cutting fluid within the cutting fluid circulation pipe in wire saw equipment, since a cutting fluid circulation pipe

THIS PAGE BLANK (USPTO)

will be got blocked by it, unless cutting fluid is exchanged frequently, it becomes impossible to carry out continuous running of long duration. It is thought that it is produced since precipitate and condensation of a sludge have the large specific gravity of the iron which constitutes a rare earth alloy, and rare earth elements. When the ingot of silicon or quartz glass was cut using a wire saw, the sludge was promptly flushed with cutting fluid, precipitate and condensation of a sludge were hardly produced, and especially the big problem resulting from that was not generated until now.
[0030] this invention person found out that cutting force could be reduced by using the drainage system cutting fluid which has the surface tension of the predetermined range instead of using water as cutting fluid. As for the surface tension in 25 degrees C of drainage system cutting fluid, it is desirable that it is within the limits of 33 mN/m - 49 mN/m so that it may mention later. Since the permeability (wettability or concordance) over the cutting edge containing a diamond system abrasive grain is excellent compared with water, the drainage system cutting fluid which has the above-mentioned surface tension within the limits is considered for drainage system cutting fluid to permeate efficiently the cutting section (part by which a rare earth alloy and a cutting edge contact and a rare earth alloy is cut). In addition, the surface tension of cutting fluid is measured using the DEYUNUI surface tension balance known well. Moreover, since water is used as a principal component and the specific heat is generally large compared with cutting oil (straight mineral oil is included typically), drainage system cutting fluid is excellent in cooling effectiveness. Furthermore, there is also an advantage which can prevent having a bad influence on natural environment by abandonment processing of cutting fluid.
[0031] Although the drainage system cutting fluid used by the cutting approach of this invention was specified using the surface tension of 25 degrees C, the temperature of the drainage system cutting fluid at the time of actually using it is not restricted to 25 degrees C. However, in order to acquire the effectiveness of this invention, it is desirable to use the drainage system cutting fluid by which temperature control was carried out within the limits of 15 degrees C - 35 degrees C. For example, in early stages, when using it, circulating cutting fluid, the temperature of the cutting fluid supplied at the comparatively low temperature of room temperature extent rises with steps, when cutting fluid absorbs the frictional heat generated between a wire and a rare earth alloy. While using it, circulating cutting fluid, the temperature of cutting fluid can exceed about 50 degrees C. Since it depends for the surface tension of a liquid on temperature as known well, if it separates not much from the temperature requirement of the above [ the temperature of the actually used drainage system cutting fluid ], the surface tension of drainage system cutting fluid will be in the condition of having resembled well the condition of having separated from the above-mentioned numerical range, and a cutting efficiency will fall.
[0032] The surface tension of drainage system cutting fluid can be easily adjusted within

the limits of the above by adjusting a glycol (a glycol derivative being included), and the class and amount of a surfactant to add. The surface tension of the above-mentioned range can also be obtained by replacing with these and adding in water the so-called synthetic lubricant called "synthetic [ synthetic (Synthetic) ]." These can also be mixed and used.

[0033] When water is used as cutting fluid, it is thought that above-mentioned fault occurred in the following reasons.

[0034] The width of face of the cutting slot formed in a rare earth alloy with a wire is narrow (for example, 0.3mm or less) one, and it is difficult to supply direct cutting fluid to a cutting slot, and cutting fluid is supplied to a wire and supplied to cutting Mizouchi in the condition of having made it adhering to a wire. If the wettability to the wire of the cutting fluid supplied by such approach is low, it will become easy to be desorbed from a wire, sufficient amount will no longer be supplied to cutting Mizouchi, and the effectiveness of cutting fluid will fall. Furthermore, the permeability to the cutting edge of cutting fluid also falls.

[0035] That is, the cutting fluid of sufficient amount for cutting Mizouchi is not supplied, but if the permeability to a cutting edge is low, it will increase, a cutting efficiency will fall, possibility that a wire piece will be generated will become high, and cutting force will also produce the problem that the process tolerance of the cutting plane of a rare earth magnet falls further. Moreover, cutting force increases by the sludge which eccritic [ of a sludge ] fell, and the sludge of a rare earth alloy with large specific gravity became that it is hard to be discharged from a cutting slot, consequently accumulated in Mizouchi. Since it is hard compared with sludges, such as silicon, when a sludge is not discharged, cutting force will increase the sludge of a rare earth alloy remarkably. Moreover, a wire cannot fully be cooled, but the temperature of a wire carries out an abnormality rise, the anomalous attrition of a wire and abnormality degraining of an abrasive grain (typically diamond system abrasive grain) arise, and a cutting efficiency and process tolerance fall.

[0036] The drainage system cutting fluid which has the surface tension of the above-mentioned range has moderate wettability to a wire (and rare earth alloy), and is fully supplied to a narrow cutting slot. Moreover, also when using it, having circulated cutting fluid and continuous running is performed over a long time by adjusting the temperature of cutting fluid, while being able to maintain cutting fluid to the temperature of the predetermined range, the surface tension of cutting fluid is always controllable within the limits of a request. It becomes possible to prevent the increment in cutting force and to cut a rare earth alloy with a sufficient precision efficiently by this. In addition, since the lubricity and viscosity (kinematic viscosity) of cutting fluid also influence cutting-ability ability, the range of the desirable surface tension of cutting fluid may change somewhat

THIS PAGE BLANK (USPTO)

with classes of cutting fluids to be used.
[0037] In addition, especially the viscosity of cutting fluid influences eccritic [ of a sludge ]. Although the kinematic viscosity of drainage system cutting fluid is generally low compared with cutting oil, and the kinematic viscosity of drainage system cutting fluid other than a glycol system is not based on temperature but it is about 1mm2/s, the kinematic viscosity of the cutting fluid containing a glycol is comparatively high, and its temperature dependence is also large. Since it may become that a cutting slot is fully hard to be supplied even if it has the surface tension of the above-mentioned range when kinematic viscosity exceeds 67mm2/s, as for the kinematic viscosity of the cutting fluid supplied between a wire and a rare earth alloy, it is desirable that it is less than [ 67mm2/s ]. Of course, it is desirable that the temperature of cutting fluid is within the limits of 15 to 35 degrees C also in this case. Furthermore, as for the temperature of cutting fluid, it is desirable that it is within the limits of 20 to 25 degrees C.
[0038] Moreover, since viscosity is comparatively low, drainage system cutting fluid can classify rare earth alloy waste from the sludge generated by cutting easily using a magnet, and can reuse drainage system cutting fluid. For example, when carrying out the cyclic use of waste water of the drainage system cutting fluid, while preventing plugging within the circulation pipe of cutting fluid, frequent exchange of cutting fluid can be made almost unnecessary, and a run length can be remarkably improved as compared with the conventional technique. Moreover, it can prevent having a bad influence on natural environment by abandonment processing of drainage system cutting fluid. In addition, since the time amount by which a rare earth alloy is put to drainage system cutting fluid is comparatively short, the property of a rare earth alloy does not deteriorate by oxidation in the meantime.
[0039] The travel speed of a wire is quick (a part for for example, thousands of part [ for hundreds of m/- ], and m/) one, drainage system cutting fluid may foam at it, and cooling effectiveness may fall. By using the drainage system cutting fluid containing a defoaming agent, decline in the cooling effectiveness by foaming of drainage system cutting fluid can be controlled. Furthermore, the corrosion of a rare earth alloy can be controlled by using the drainage system cutting fluid which has PH within the limits of 9-11. Moreover, oxidation of a rare earth alloy can be controlled by using the drainage system cutting fluid containing a rusr-proofer. What is necessary is just to adjust these suitably in consideration of a class, processing conditions, etc. of a rare earth alloy.
[0040] (Operation gestalt) The operation gestalt of the manufacture approach of the rare earth alloy plate by this invention is explained hereafter. With this operation gestalt, what permuted a part of Nd of compound Nd-Fe-B of the ternary system which uses neodymium (Nd), iron (Fe), and boron (B) as a principal component as a rare earth alloy, or Nd-Fe-B by Dy (dysprosium), and permuted a part of Fe by Co (cobalt) is used. Nd-

Fe-B is known as a powerful neodymium magnet ingredient with which a maximum energy product exceeds 320 kJ/m3.
[0041] How to produce the ingot of Nd-Fe-B is explained briefly, referring to the flow chart of drawing 1 . In addition, the approach of producing the rare earth alloy as a magnet ingredient is indicated by for example, the U.S. Pat. No. 4,770,723 specification at the detail.
[0042] First, after carrying out weighing capacity of the raw material to a predetermined component ratio correctly at step S1 of drawing 1 , a raw material is dissolved with the RF fusion furnace of a vacuum or an argon gas ambient atmosphere at step S2. The dissolved raw material is cast to water-cooled mold, and the raw material alloy of a predetermined presentation is formed. A raw material alloy is ground at step S3, and impalpable powder with a mean particle diameter of about 3-4 micrometers is produced. Impalpable powder is put into metal mold by step S4, and press forming is carried out in a field. Press forming is performed after mixing impalpable powder with lubricant if needed at this time. Next, if an about about 1000-1200-degree C sintering process is performed at step S5, a neodymium magnet material is producible. Then, in order to raise magnetic coercive force at step S6, about 600-degree C aging treatment is performed, and production of a rare earth alloy ingot is completed. The size of an ingot is 30mmx50mmx60mm.
[0043] At step S7, cutting processing of a rare earth alloy ingot is performed, and two or more sheet metal (called a substrate or a wafer) cut from the ingot is formed. Before giving explanation after step S8, how to carry out cutting processing of the ingot of a rare earth alloy with the wire saw technique by this invention in the following is explained to a detail.
[0044] Drawing 2 (a) and (b) are referred to. First, it fixes mutually with the adhesives 22 which consist of an epoxy resin, and two or more ingots 20 produced by the above-mentioned approach are fixed to the work-piece plate 26 iron in the condition of having assembled as two or more blocks 24a-24c. Fixing between the work-piece plate 26 and each blocks 24a-24c is also attained by adhesives 22. In the detail, the base plate 28 made from carbon which functions as a dummy has been arranged more between the work-piece plate 26 and each blocks 24a-24c, and this base plate 28 made from carbon has also fixed through adhesives 22 to the work-piece plate 26 and each blocks 24a-24c. After cutting processing of Blocks 24a-24c is completed, the base plate 28 made from carbon receives cutting processing by the wire saw until downward actuation of the work-piece plate 26 stops, and is bearing a role of a dummy of protecting the work-piece plate 26.
[0045] With this operation gestalt, each block size is designed so that the size of each blocks 24a-24c measured along the direction (the "wire transit direction" is called below) shown by the arrow head A of drawing 2 (a) may be set to about 100mm. Since the size

THIS PAGE BLANK (USPTO)

measured along the wire transit direction about one ingot 20 is about 50mm, he is trying to constitute each of the above-mentioned blocks 24a-24c from this operation gestalt by piling up what arranged the ingot 20 whose number is two along the wire transit direction.

[0046] Although two or more ingots 20 fixed to the work-piece plate 26 are called a "work piece" as a whole, the following advantages are born by dividing this work piece into two or more blocks.

[0047] When the wire transit direction size (the die length of a cutting slot) becomes large too much about the work piece of 1 padding exceeding the amount of drawing in of cutting fluid, the field where cutting fluid supply becomes inadequate among the cutting processing parts of a work piece occurs, and there is a possibility that a wire open circuit may arise by this. However, since the work piece of this operation gestalt is divided into the blocks 24a-24c of suitable size, it becomes possible to supply cutting fluid to the clearance between Blocks 24a-24c, and it can solve the problem that cutting fluid supply is insufficient. Moreover, since the sludge which accumulated between abrasive grains can also be flushed by this, cutting efficiency also improves.

[0048] In order to supply cutting fluid to the clearance between Blocks 24a-24c, he arranges two cutting fluid delivery pipes 29 in the upper part of the work-piece plate 28, and is trying to inject fresh cutting fluid downward out of the cutting fluid delivery pipe 29 through slit-like nozzle 29a with this operation gestalt. The cutting fluid delivery pipe 29 receives the cutting fluid with which the fresh cutting fluid which does not contain a sludge, or a sludge was removed from the cutting fluid service tank mentioned later. The cutting fluid delivery pipe 29 has the structure of a double tube type, and the width of face of downward slit 29a changes to a longitudinal direction, and it is designed so that uniform cutting fluid supply may be realized.

[0049] Although the work piece is divided into two or more blocks as mentioned above with this operation gestalt, as what magnitude the wire transit direction size about each of each blocks 24a-24c should be set changes also with the surface tension and the wire travel speeds of cutting fluid. Moreover, the number of ingots 20 and arrangement which constitute one block also change with the magnitude of each ingot 20. What is necessary is just to divide a work piece into the block of the optimal size suitably in consideration of these. Moreover, although the cutting fluid delivery pipe 29 is formed in the work-piece plate 26 bottom, you may make it supply cutting fluid between blocks with the work-piece plate 26 down side in this operation gestalt.

[0050] Next, the principal part 30 of the wire saw equipment suitably used with this operation gestalt is explained, referring to drawing 3 A and drawing 3 B. This wire saw equipment is equipped with three Maine rollers 34a-34c with which one wire 32 is twisted also around many [-fold ]. Among these, although two Maine rollers 34a and 34b

THIS PAGE BLANK (USPTO)

are supported free [ rotation ] by wire saw equipment, it does not connect with the driving means of a motor etc. directly, but they function on it as a follower roller. On the other hand, it connects with the non-illustrated driving source, for example, motor, and by this driving source, Maine roller 34c can receive a desired turning effort, and can be rotated at a setting rate. Maine roller 34c functions as a driving roller in order to transmit turning effort to two Maine rollers 34a and 34b through a wire 32.
[0051] A wire 32 is guided receiving the tension of several kg-wt according to rotation of the Maine rollers 34a-34c, and it is rolled round from the non-illustrated reel by the reel which is not illustrated [ other ], carrying out both-way transit at a predetermined rate (a part for for example, 600-1000m/).
[0052] Two or more slots are formed in the periphery front face of the Maine rollers 34a-34c at equal intervals, and as one wire 32 is inserted in much Mizouchi, it is twisted around each roller. The array pitch (spacing of a wire train) of a wire 32 is prescribed by the pitch of this slot. With this operation gestalt, this pitch is set as about 2.0mm. Since this pitch is set up according to the thickness of the sheet metal which should be cut down by cutting processing, it will choose and use the multi-slot rollers 34a-34c which had a suitable pitch suitably.
[0053] A wire 32 is formed from a hard drawn steel wire (piano wire), and, as for the size, an about 0.06-0.25mm thing is used. The cross-section configuration of a wire is shown in drawing 6 . In the front face of the wire core wire 61 used with this operation gestalt, the diamond abrasive grain 62 whose particle size is 30-60 micrometers has fixed with the resin film 63 so that drawing 6 may show. The resin film 63 is formed from phenol resin etc., and the thickness is 30-60 micrometers. As for spacing of abrasive grain 62 in the condition of having fixed, it is desirable that it is about 2 to 4 times the diameter of an abrasive grain 62. Moreover, it can replace with the resin film 63 and the diamond abrasive grain 62 can also be fixed by metal membranes, such as nickel.
[0054] In addition, the wire core wire 61 may be formed from what bundled refractory metals, such as alloys, such as nickel-Cr and Fe-nickel, W, and Mo, or nylon fiber. Moreover, the ingredient of an abrasive grain may not be limited to a diamond, but may be SiC, B, C, CBN (Cubic BoronNitride), etc.
[0055] A work piece is pressed against the part stretched and passed between Maine roller 34a and Maine roller 34b among the wires 32 it runs on the occasion of cutting processing processing. With this operation gestalt, cutting fluid can be supplied on a wire 32 from at least three places, and cutting fluid supply from two places is performed using the clearance between blocks using the pipe 29 and slit-like nozzle 29a which have been arranged in the upper part of the work-piece plate 26 among those. Cutting fluid supply from remaining one place is performed using a nozzle 36 in drawing 3 B from the left-hand side of a work piece. In addition to these nozzles 29a and 36, supply of cutting fluid

may be additionally performed from the location on the right-hand side of a work piece in drawing 3 B, using other nozzles.

[0056] Furthermore, like [ the case where cutting fluid especially with low viscosity is used, and when the travel speed of a wire 32 is quick (a part for for example, 1000m/above) ], when it is hard to supply cutting fluid to a wire 32, as shown in drawing 3 B, cutting fluid can be more certainly supplied to a wire 32 by making it run the inside of the cutting fluid supplied by overflowing from cutting fluid tub 38 opening in a wire 32 (for example, refer to JP,11-198020,A).

[0057] With this operation gestalt, surface tension supplies the drainage system cutting fluid of 33 mN/m - 49 mN/m within the limits between a work piece and a wire. The width of face of the cutting slot formed in a work piece is very as narrow as about 0.3mm or less typically, and it is difficult to supply cutting fluid to a cutting slot directly. For this reason, cutting fluid is supplied to a wire, Mizouchi is made to draw this and it is made to discharge out of a slot after that with a wire. Thus, if the surface tension supplied is lower than 33 mN/m or higher than 49 mN/m, the wettability to a wire will be bad, and will not be supplied in sufficient quantity of a cutting fluid fang furrow, the sludge formed from a rare earth alloy with large specific gravity will become that it is hard to be discharged from a cutting slot, consequently cutting force will go up. Moreover, if sufficient quantity of cutting fluid is not supplied to cutting Mizouchi, lubricity sufficient between a wire and a rare earth alloy will not be obtained (sharpness falls), but the field roughness and dimensional accuracy of a cutting plane will worsen. Moreover, it is not controlled in the range where coefficient of friction of a cutting edge is proper, consequently the anomalous attrition of an abrasive grain happens, and the problem that the abrasiveness of a wire becomes high is also produced. Consequently, the life of a wire becomes short while cutting efficiency falls greatly.

[0058] On the other hand, if the drainage system cutting fluid which has the surface tension of above-mentioned within the limits is used, since it will be supplied in sufficient quantity of a cutting fluid fang furrow, promptly, the sludge (namely, rare earth alloy powder with large specific gravity (the specific gravity of for example, a neodymium alloy is about 7.5)) produced in cutting Mizouchi of a rare earth alloy is flow, and is eliminated from a cutting field in the exterior of a cutting slot (high discharge effectiveness). For this reason, the wire piece by the increment in cutting force and the problem of a cutting efficiency fall can be solved, without the sludge which accumulated in cutting Mizouchi barring transit of a wire strongly. Moreover, it is controlled in the range where coefficient of friction in a cutting edge is also proper. Furthermore, since the specific heat is high compared with cutting oil, drainage system cutting fluid is excellent also in cooling effectiveness, and can control and prevent the abnormality rise of the temperature by friction efficiently. Moreover, since viscosity is comparatively low, the

amount of the sludge carried by even the Maine roller with the wire it runs is also reduced, and drainage system cutting fluid can also control the phenomenon in which a sludge accumulates in Mizouchi on the Maine roller. Consequently, a wire piece is prevented and there is also an advantage that a wire can be easily removed from a work piece after work-piece cutting termination.

[0059] As drainage system cutting fluid, glycol system cutting fluid (YUSHIRO CHEMICAL INDUSTRY [ CO., LTD. ] make: WL-2) can be used, for example. With the class and molecular weight of the glycol to be used, the drainage system cutting fluid of desired surface tension can be prepared by adjusting the addition to water.

[0060] Moreover, the cutting fluid which added the surfactant can also be used for water. As a surfactant, ARUKI roll amide systems, such as polyhydric-alcohol systems, such as polyoxyethylene systems, such as polyoxyethylene alkyl phenyl ether and polyoxyethylene mono-fatty acid ester, and sorbitan mono-fatty acid ester, or fatty-acid diethanolamide, can be used as an anion system as sulfonic acid types, such as sulfate molds, such as fatty-acid derivatives, such as fatty-acid soap and naphthenic-acid soap, or a long-chain alcoholic sulfate, and sulfated oil of animal and vegetable oils, or a petroleum sulfonate, and a non-ion system. Specifically, surface tension can be adjusted within suitable limits by adding chemical solution type JP-0497N (castrol company make) about 2% of the weight in water.

[0061] Furthermore, the cutting fluid which added synthetic lubricant can also be used for water. As synthetic type composition lubricant, a synthetic solution type, a synthetic emulsion type, and a synthetic soluble type can be used, and also in it, a synthetic solution type is desirable and, specifically, can mention SHINTAIRO#870 [ 9954 (castrol company make) ] (YUSHIRO CHEMICAL INDUSTRY CO., LTD. make). All can adjust surface tension within suitable limits by adding about 2% of the weight in water.

[0062] Moreover, the corrosion of a rare earth alloy can be prevented by making cutting fluid contain a rust preventive. Here, as for PH, being referred to as 9-11 is desirable. As a rust preventive, a phosphoric acid salt, a borate, molybdate, a tungstate, or a carbonate can be used as amines, such as carboxylate, such as oleate and a benzoate, or triethanolamine, and an inorganic system as an organic system.

[0063] Moreover, nitrides, such as bends triazole, can be used as nonferrous metal anticorrosives, and formaldehyde donators, such as hexa hydro triazine, can be used as antiseptics, for example.

[0064] Moreover, a silicone emulsion can be used as a defoaming agent. By making a defoaming agent contain, foaming of cutting fluid is lessened, the permeability to the cutting slot on the cutting fluid is improved, the cooling effect increases, and an abnormality rise and anomalous attrition of the temperature of a wire 32 stop being able to happen easily.

THIS PAGE BLANK (USPTO)

[0065] Such drainage system cutting fluid cannot pollute an environment easily compared with non-water solubility cutting fluid (oil). Moreover, the danger of emitting smoke and ignition is safe for drainage system cutting fluid few, and if drainage system cutting fluid is used, work environment is improvable, since an oil mist is not generated. Furthermore, since it is easy to remove a sludge, drainage system cutting fluid is also an ingredient suitable for a reuse (cyclic use of waste water).

[0066] Drawing 3 B is referred to. On the occasion of cutting processing processing of a work piece, the work-piece plate 26 is moved along with an arrow head D downward at the rate of predetermined (a part for for example, 0.5-1.0mm/) by the non-illustrated driving gear, and pushes the work piece fixed to the work-piece plate 26 against the wire 32 it runs in a level longitudinal direction (the direction of arrow-head A). By supplying the cutting fluid of amount sufficient between a work piece and a wire 32, a sludge can be discharged from between a work piece and wires 32, and a work piece can be continuously cut by it. Although cutting efficiency will improve if fall velocity of the work-piece plate 26 is made quick, since cutting force goes up, the flapping phenomenon of a wire 32 occurs, and there is a possibility that the flatness of a work-piece cutting plane may worsen. Flatness degradation of a work-piece cutting plane increases the time amount which a polish activity at a next process takes, or makes the probability of occurrence of a defective increase. Therefore, it will be necessary to set up the fall velocity of a work piece, i.e., the cutting speed of a work piece, within suitable limits.

[0067] The wire 32 arranged at constant pitch carries out grinding of the work piece as a multi-wire saw, the channel depth is increased, carrying out coincidence formation of many processing slots (cutting slot) in connection with it at a work piece, and cutting processing is made to advance by descent of a work piece. When a processing slot crosses each ingot completely, cutting processing of the ingot is attained and many wafers of the thickness decided by the pitch of a wire train and the size of a wire are cut down by coincidence. After cutting of all the ingots 20 is completed, the work-piece plate 26 is raised along with an arrow head D by the above-mentioned driving gear. Then, while each block is separated from the work-piece plate 26, the cut wafer will be separated from each block.

[0068] With this operation gestalt, in order to perform cutting processing, dropping a work piece from the upper part of a wire 32, the work-piece plate 26 descends with the condition of having combined with the work-piece plate 26 still more the ingot 20 which received cutting processing with adhesives. Thus, since it is located under the wire, even if the part of a work piece processed [ cutting ] dissociates and falls out from the body of a work piece, there is no possibility of 20 ingot which received cutting processing that the omission part may contact a wire 32 again. Therefore, an alloy plate [ finishing / cutting processing ] will be turned to the following process in the state of high quality.

[0069] Next, the outline configuration of the cutting fluid circulation system of wire saw equipment 40 is explained, referring to drawing 4 . As typically shown in drawing 4 , while supplying cutting fluid to the principal part 30 of wire saw equipment, in equipment 40, the cutting fluid circulation system for collecting the used cutting fluid containing the sludge formed of processing is prepared.

[0070] In the case of this equipment 40, on the occasion of cutting processing of a work piece, cutting fluid is supplied to the cutting fluid delivery pipe 29 on the work-piece plate 26 shown in drawing 3 A and drawing 3 B and a nozzle 36, or the cutting fluid tub 38 of drawing 3 C through the 1st circulation pipe 44 from the cutting fluid service tank 42. A pump P1 is used at this time. The cutting fluid used for cutting processing is dropped from a processing part and its circumference, and is received by the recovery drain 37 located caudad and its processing machine drain 37' prepared caudad. Cutting fluid is carried to ****** 54 through the 2nd circulation pipe 46 from the recovery drain 37 and processing machine drain 37', and after it receives the sludge separation processing by the magnetic separator 50 mentioned later there, it is accumulated in the recovery tank 48. The cutting fluid which returned to the condition near the condition before cutting processing is sent to the cutting fluid service tank 42 through the 3rd circulation pipe 49 by this sludge separation processing. A relay pump P2 is used at this time. Filter F is inserted in the middle of the 3rd circulation pipe 49, and Filter F can remove the sludge which was not removed by the magnetic separator 50. As a filter F, a saccate bag filter is used suitably.

[0071] In addition, the cutting fluid service tank 42 can settle the detailed sludge which might penetrate Filter F. For this reason, it is possible to reduce further the amount of the sludge which remains in the cutting fluid sent to the principal part 30 through the 1st circulation pipe 44. At this time, since the magnetic separator 50 is magnetized, it condenses and a detailed sludge is easy to precipitate by it.

[0072] Thus, with this operation gestalt, in order to perform separation removal (filtering) of a sludge efficiently, performing supply and recovery of cutting fluid cyclically, it enables it to prolong spacing of a cutting fluid exchange activity remarkably, and to continue cutting processing processing continuously over long duration. In addition, in order to maintain the surface tension of cutting fluid to request within the limits, water or new cutting fluid may be supplied with a suitable time interval. In this case, when surface tension of cutting fluid is surveyed periodically and surface tension separates out of a setting range, you may make it supply water or new cutting fluid in equipment (for example, cutting fluid service tank 42) at any time. Partial supply of such cutting fluid differs from whole-quantity-exchange of cutting oil greatly at the point which can be performed without interrupting cutting processing processing.

[0073] Next, a magnetic separator 50 is explained, referring to drawing 5 . This magnetic

separator 50 can separate a sludge from the separation tub 54 which stored the used cutting fluid (dirty liquid) 52 containing a sludge using magnetism. Separation wall 54a is prepared in the separation tub 54. This separation wall 54a has the function to make a big sludge sediment to the separation tub 54. The fine sludge which was able to float in dirty liquid 52 and was able to overcome separation wall 54a with dirty liquid 52 will be magnetically separated by the approach of explaining in full detail below.

[0074] The magnetic separator 50 is equipped with the drum 56 on which the powerful magnet has been arranged inside, and the squeezing roller 57 which rotates while sticking to a part of peripheral face of a drum 56. Being supported pivotable centering on a fixed shaft, the drum 56 is arranged so that cutting fluid 52 may be partially contacted within the separation tub 54. The squeezing roller 57 is formed from oil resistant rubber etc., and a pressure welding is carried out by the energization force of a spring to the peripheral face of a drum 56. If a drum 56 rotates in the direction of an arrow head by the non-illustrated motor, the rotation will give frictional force to a squeezing roller 57, and will carry out the rotation drive of the squeezing roller 57.

[0075] The sludge which floats in cutting fluid 52 sticks to the peripheral face of the rotating drum 56 with the magnet in a drum 56. The sludge which stuck to the peripheral face of a drum 56 is removed out of cutting fluid 52 with rotation of a drum 56, and passes through between a drum 56 and squeezing rollers 57. Soon, by the scraper 58, a sludge is scratched from the front face of a drum 56, and are collected in the sludge box 59. Thus, the cutting fluid from which the sludge was removed is carried by the recovery tank 48 with a pipe 60 from the edge in the longitudinal direction of a drum 56. The structure of a desludging means usable as such a magnetic separator 50 is indicated by JP,63-23962,Y. According to the experiment of the artificer who explains later, in order to draw near to the front face of a drum 56 the sludge of the rare earth alloy in cutting fluid, it is desirable to make the magnetism in the peripheral face (sludge recovery side) of the drum 56 in cutting fluid 52 into 0.27 teslas or more, and it is still more desirable to make it 0.3 teslas or more. By having used drainage system cutting fluid with low viscosity, the advantage of making easy recovery of the rare earth alloy sludge by the magnetic separator 50 can also be acquired. It is because the viscous drag which the sludge which moves in the inside of the field formed into cutting fluid 52 receives is reduced, so it becomes possible to collect many sludges efficiently.

[0076] If a sludge is efficiently removed using such a separator, since the sludge which can maintain low the concentration of the sludge contained in the cutting fluid by which the cyclic use of waste water is carried out, and is supplied to a cutting edge with cutting fluid can be lessened, the cutting load which a wire receives can be maintained at level small enough over a long period of time by the work-piece cutting plane.

[0077] Hereafter, the configuration of the cutting fluid circulation system 70 of another

gestalt equipped with the temperature control machine is explained, referring to drawing 7 and drawing 8 . In addition, the same reference mark is attached about the part which has the same configuration to the circulation system shown in above-mentioned drawing 4 and drawing 5 . Below, the part which has a different configuration from the circulation system shown in above-mentioned drawing 4 and drawing 5 is mainly explained.
[0078] In the cutting fluid circulation system 70 shown in drawing 7 , cutting fluid is supplied to the principal part 30 of wire saw equipment through the 1st circulation pipe 76 on the occasion of cutting processing of a work piece from a purge 72. The dirty liquid received on the other hand by the recovery drain 37 and processing machine drain 37' which were prepared in the principal part 30 is carried by the purge 72 through the 2nd circulation pipe 78, and after it receives the sludge separation processing by an above-mentioned magnetic separator 50 and an above-mentioned bag filter 84 there, it is accumulated in the recovery tank 48 (the separation tub 82 and temperature control tub 92).
[0079] On the whole in the principal part 30, the temperature of the cutting fluid which circulates through a circulation system 70 rises by absorbing the frictional heat generated between a wire and a rare earth magnet. A rise of the temperature of cutting fluid will increase the cutting force in cutting by the short supply to the cutting slot of the cutting fluid resulting from the surface tension of cutting fluid, and decline in cooling effectiveness. On the other hand, in a circulation system 70, the temperature of the cutting fluid by which the cyclic use of waste water is carried out is maintainable in a predetermined temperature requirement using the temperature control machine 74 connected to the purge 72. As a temperature control machine 74, the well-known temperature control machines (for example, temperature controller given in JP,8-25125,B etc.) equipped with the heat exchanger etc. could be used, and the temperature control machine 74 is preferably equipped with both the cooling function and the heating function.
[0080] The temperature control machine 74 is controlled to operate, when the temperature of cutting fluid rises exceeding a predetermined value, and can control the temperature of the cutting fluid supplied to the principal part 30 to predetermined within the limits. Thus, if temperature control of cutting fluid is performed, since it will maintain the surface tension of the cutting fluid supplied between a wire and a rare earth magnet within suitable limits and cutting force will not be made to increase, cutting fluid cannot be exchanged but ** can also perform cutting of a rare earth magnet continuously.
[0081] Next, the configuration of a purge 72 is explained, referring to drawing 8 . This purge 72 consists of the separation section 80 equipped with an above-mentioned magnetic separator 50 and the above-mentioned separation tub 82, and a temperature controller 90 equipped with the temperature control tub 92. The separation tub 82 and the

THIS PAGE BLANK (USPTO)

temperature control tub 92 are separated by the septum 88, and a septum 88 prevents that cutting fluid moves freely between tubs. In the upper part of a septum 88; free passage section 88a (clearance between the septum partial upper parts which has height lower than the height of the side attachment wall of each tubs 82 and 92 in the gestalt shown in drawing 8 ) is formed, and cutting fluid can move through free passage section 88a between tubs. That is, the separation tub 82 and the temperature control tub 92 are connected possible [ a free passage ] so that a fluid can move only in the location of the upper part of each tub.

[0082] In the separation section 80, the dirty liquid carried from wire saw equipment is supplied to a magnetic separator 50 and a bag filter 84. A magnetic separator 50 has the capacity to process a lot of cutting fluid for a short time, and is suitable for removing a comparatively large sludge. On the other hand, the bag filter is suitable for removing a comparatively small sludge. If the supply rate of the cutting fluid to each decollator is appropriately set up according to the throughput of each decollator (a magnetic separator 50 and bag filter 84), the magnitude of the sludge contained in cutting fluid, an amount, etc., it is possible to make a sludge separate efficiently. A magnetic separator 50 and the supply rate of the cutting fluid to a bag filter 84 are set as 8:2. However, the gestalt of a decollator may be a gestalt which filters some cutting fluid which was not restricted to this, for example, came out of the magnetic separator 50 with a bag filter 84.

[0083] The cutting fluid from which the sludge was removed by the magnetic separator 50 is carried to the separation tub 82 with a pipe 85 from the edge in the longitudinal direction of a drum 56. Moreover, the cutting fluid from which the sludge was removed with the bag filter 84 is carried to the separation tub 82 with a pipe 86. The volume of the separation tub 82 is set as about 200 L.

[0084] From opening of pipes 85 and 86, by the septum 88, the cutting fluid which flowed into the separation tub 82 piles up in the separation tub 82 temporarily, and does not flow into the temperature control tub 92 directly. Therefore, the sludge which was able to be removed neither with a magnetic separator 50 nor a bag filter 84 can be made to sediment in the separation tub 82. Consequently, only the supernatant part of the cutting fluid in the separation tub 82 flows into the temperature control tub 92 over a septum 88.

[0085] The sludge which sedimented by the separation tub 82 is returned to a magnetic separator 50 with the sludge absorption pump 87. The opportunity into which can reduce the amount of the sludge in the separation tub 82, and such a sludge is made by this to divide by the magnetic separator 50 again can be obtained. If it does in this way, the desludging engine performance of a purge 72 can be raised.

[0086] In addition, in order to make a sludge sediment [ near the inhalation opening of the sludge absorption pump 87 ], preventing that a sludge soars near the oil level of

THIS PAGE BLANK (USPTO)

cutting fluid, it is desirable to prepare a ramp, to collect sludges or to set the location of opening of pipes 85 and 86 as a septum 88, as shown in drawing 8 .

[0087] The supernatant part of the cutting fluid which set separation tub 82 and was formed moves to the temperature control tub 92 through free passage section 88a. The volume of the temperature control tub 92 is set for example, as 400L. The cutting fluid supplied to the temperature control tub 92 does not contain most sludges.

[0088] Thus, the cutting fluid accumulated in the temperature control tub 92 is again returned to the temperature control tub 92, after being sent to the temperature control machine 74 (refer to drawing 7 ) using a pump P3 and lowering temperature. Since it is made to remove a sludge in the separation section 80 before sending cutting fluid to the temperature control machine 74, when a sludge collects in a pipe in the temperature control machine 74, heat exchange effectiveness cannot fall and temperature control of cutting fluid can be performed effectively.

[0089] With this operation gestalt, when the temperature of the cutting fluid in the temperature control tub 92 becomes beyond predetermined temperature, a pump P3 and the temperature control machine 74 are operated, and when the temperature of the cutting fluid in the temperature control tub 92 turns into below predetermined temperature after that, the pump P3 and the temperature control machine 74 are stopped. Therefore, all the cutting fluid held in the temperature control tub 92 is not sent to the temperature control machine 74, and some cutting fluid is sent to it in a predetermined period. Some cutting fluid which temperature control was carried out and was returned, and the remaining cutting fluid in the temperature control tub 92 are mixed by the agitator 94 (stirring), and, thereby, the temperature of the cutting fluid in the temperature control tub 92 is equalized. If it does in this way, it will be prevented that the temperature of the cutting fluid supplied to the principal part of wire saw equipment changes rapidly compared with the case where the cutting fluid which carried out temperature control is sent to the principal part of direct wire saw equipment. If cutting fluid can be supplied at the temperature stabilized to the principal part of wire saw equipment, since the surface tension of cutting fluid etc. will not change a lot, wire saw equipment can perform stable cutting. Thus, with this operation gestalt, the temperature of the cutting fluid in the temperature control tub 92 is maintainable to a predetermined temperature requirement, operating the temperature control machine 74 effectively.

[0090] On the other hand, under the effect of a room temperature etc., the temperature of cutting fluid may fall and the surface tension of cutting fluid may become large across the predetermined range. In this case, cutting fluid becomes that a cutting slot is fully hard to be supplied, eccritic [ of a sludge ] falls, and cutting resistance increases. Moreover, the fall of the desludging capacity by the magnetic separator may also be produced. Furthermore, coefficient of friction in a cutting edge rises, and wear of an abrasive grain

THIS PAGE BLANK (USPTO)

becomes intense. When such, it is advantageous to raise the temperature of cutting fluid using the temperature control machine 72, and to reduce the surface tension of cutting fluid.

[0091] Moreover, the cutting fluid containing a glycol has comparatively high kinematic viscosity, and its temperature dependence of kinematic viscosity is also large. Since it may become that a cutting slot is fully hard to be supplied even if it has the surface tension of the above-mentioned range when kinematic viscosity exceeds 67mm2/s, as for the kinematic viscosity of the cutting fluid supplied between a wire and a rare earth alloy, it is desirable that it is less than [ 67mm2/s ]. Therefore, in using the cutting fluid containing a glycol, while surface tension is in the above-mentioned range, it is desirable to control temperature so that kinematic viscosity may become less than [ 67mm2/s ].

[0092] The cutting fluid by which temperature control was carried out in the temperature control tub 92 is sent to the principal part 30 ( drawing 7 ) of wire saw equipment with a pump P4. The temperature of the cutting fluid supplied between a wire and a rare earth magnet is controlled to become 15 degrees C - 35 degrees C preferably, and is controlled by 20 degrees C - 25 degrees C still more preferably.

[0093] With an above-mentioned operation gestalt, while performing separation removal of a sludge efficiently, performing supply and recovery of cutting fluid cyclically, the surface tension of cutting fluid is maintained in the suitable range by performing temperature control of cutting fluid. If it does in this way, by discharging a sludge appropriately from a cutting slot and maintaining cutting force on low level, cutting efficiency can be raised and precision of a cutting plane can be made high. Therefore, it enables it to prolong spacing of exchange of cutting fluid remarkably and to continue cutting processing processing continuously over long duration.

[0094] Next, the effect of surface tension to the sectility ability at the time of using glycol content drainage system cutting fluid is explained, referring to drawing 9 and drawing 10 .

[0095] Drawing 9 shows the configuration of the testing machine (evaluator) 10 which conducted the experiment shown in drawing 10 mentioned later. The volume drum 102 by which, as for the testing machine 10, the wire 12 for cutting was wound around the peripheral face, and the revolving shaft was connected to the drive motor (un-illustrating), In two or more pulleys 106 which show again a wire 12 to the volume drum 102 from the volume drum 102 through the cutting section 104 which cuts the cut object (work piece) 14, and the cutting section 104 It has migration equipment 108 to which the cut object 14 can be linearly moved toward a wire 12 (it presses). Moreover, the tension adjustment 110 is formed in the middle of the path of a wire 12. By giving the energization force F to an outside to the movable pulley 112 around which the wire 12 was wound almost, the tension adjustment 110 can give tension to a wire 12, and,

thereby, can prevent the slack of a wire 12. further -- the tension adjustment 110 -- a work piece 14 -- pressing -- etc. -- when the tension more than predetermined works on a wire 12, the movable pulley 112 moves inside against the above-mentioned energization force F -- it is constituted so that things can be carried out. While this eases the tension applied to a wire 12, a wire 12 can maintain at a balance the stress given to a work piece 14 (that is, push reliance of a wire is performed by the constant pressure to a work piece 14). As a wire 12, diameter of core wire 0.18mmphi, diameter of result 0.24mmphi, breaking load 7 - 8.5kgf, 40-60 micrometers of diameters of an abrasive grain, and 30 micrometers - 60 micrometers of phenol resin coating thickness were used.

[0096] The cutting fluid supply nozzle 114 is formed above wire 12' of the cutting section 104, and cutting fluid is dropped or injected from a nozzle 114 to wire 12'. The temperature of the cutting fluid which the cutting fluid supplied to wire 12' is discarded, without carrying out the cyclic use of waste water, therefore is supplied to wire 12' is kept almost constant.

[0097] Using this testing machine 10, glycol content drainage system cutting fluid was made dropped at wire 12' from a nozzle 114, and sectility ability was measured. In addition, congruence directional movement of wire 12' was carried out by linear velocity 200 m/min by reversing the hand of cut of the volume drum 102 periodically. Moreover, by setting up appropriately the passing speed of the energization force F and migration equipment 108, the work piece 14 was pressed by 4 Ns of constant pressures to wire 12', and it cut by the constant-pressure load. In addition, the work piece 14 is formed from the rare earth sintered magnet of the letter of a block.

[0098] As cutting fluid, the various glycol content drainage system cutting fluid (YUSHIRO CHEMICAL INDUSTRY [ CO., LTD. ] make: WL-1-WL-5) with which surface tension differs was used at the temperature of about 25 degrees C. The surface tension in 25 degrees C of the used cutting fluid is 33.6 mN/m - 48.9 mN/m. Moreover, cutting oil (YUSHIRO CHEMICAL INDUSTRY [ CO., LTD. ] make: HT-9, 25-degree C surface tension:29.6 mN/m) was made into the reference sample.

[0099] the surface tension [mN/m] of cutting fluid from which drawing 10 was obtained using the testing machine 10, and sharpness fall multiplier alpha[-- %/unit -- a logarithm -- it is the graph which shows relation with time amount] and sectility ability constant gamma [%]. The sectility ability constant gamma is a parameter which shows the sectility ability (sharpness) in the early stages of cutting, and it is thought that it is especially influenced by sludge eccritic etc. The sharpness fall multiplier alpha is a parameter showing the decreasing rate (alpha< 0) of the sectility ability about time amount, and it is thought that especially wear of a wire is shown. A concrete target is a value with which the sectility ability constant gamma and the sharpness fall multiplier alpha are satisfied of the following formulas (1).

[0100] Y=alpha ln (t) +gamma (1)
In a formula (1), t expresses cutting time amount (however, let 3 minutes be one unit), and Y expresses a sectility ability ratio. The sectility ability ratio Y is defined as sectility ability when setting initial sectility ability at the time of using the above-mentioned cutting oil to 100. Sectility ability is determined by measuring the cutting depth of flute formed in the rare earth alloy with the wire. in addition, a formula (1) to the sectility ability constant gamma -- the sectility ability ratio (opposite cutting oil) of 3 minutes after (t= 1) -- expressing -- the sharpness fall multiplier alpha -- a logarithm -- it turns out that the rate of change of the cutting-ability ability to time amount (ln (t)) is expressed.
[0101] When the surface tension in 25 degrees C uses the glycol content drainage system cutting fluid of 33.6 mN/m - 48.9 mN/m so that the graph of drawing 10 may show, the sectility ability constant gamma is under 100 [%], and its sectility ability is lower than the case where the above-mentioned cutting oil is used. However, the sectility ability constant gamma of each water-soluble cutting fluid has exceeded 75 [%], and if sectility ability of this level is obtained, it is possible to cut a rare earth alloy comparatively efficiently. moreover, the case where the glycol content drainage system cutting fluid which has the surface tension of the above-mentioned range is used -- the sharpness fall multiplier alpha -16.5[-- %/unit -- a logarithm -- time amount] -- it is above, and also when it cuts by carrying out long duration continuation, it turns out that sharpness does not fall so greatly. When the value of this sharpness fall multiplier alpha was compared with the sharpness fall multiplier at the time of using cutting water (tap water), it was a value good enough.
[0102] Thus, when using the drainage system cutting fluid of glycol content, a cutting efficiency worsens compared with the case where specific cutting oil is used, but on the other hand since an oil mist etc. does not occur, the advantage that workability becomes good is acquired. Moreover, it is more desirable for drainage system cutting fluid to be unable to pollute an environment easily, and to use drainage system cutting fluid rather than cutting oil at this point. Moreover, since it is comparatively easy to remove a sludge from drainage system cutting fluid, when circulating through and using cutting fluid, drainage system cutting fluid may be an ingredient more suitable than cutting oil.
[0103] It is desirable that the surface tension in 25 degrees C uses the drainage system cutting fluid of about 33 mN/m - about 49 mN/m from an above-mentioned result and the result examined variously. It is desirable that the surface tension in 25 degrees C uses the drainage system cutting fluid (for example, :WL[ by YUSHIRO CHEMICAL INDUSTRY CO., LTD. ]- 2) of 35 mN/m - 45 mN/m especially. It is possible to cut a rare earth alloy efficiently, without causing environmental pollution etc., if such drainage system cutting fluid is used.
[0104] Drawing 11 shows the relation between the magnetism in the sludge recovery side

THIS PAGE BLANK (USPTO)

(sludge recovery area) of a magnetic separator, and the flatness of a work-piece cutting plane, and the relation of the magnetism and sludge discharge (amount per hour of the sludge removed from cutting fluid) in the sludge recovery side (sludge recovery area) of a magnetic separator. In addition, the data shown in drawing 11 were obtained under the conditions on which a 1kg [/hour ] sludge is incorporated in cutting fluid from a work-piece cutting plane. Using the gauss meter and the probe (both bell company make), the magnetism at this time (surface inductive flux) contacted the probe to the sludge recovery side, and measured it.
[0105] If the magnetism of a magnetic separator increases so that drawing 11 may show, a sludge discharge will increase in connection with it, and the flatness of a work-piece cutting plane will improve. When there are few sludge discharges from the cutting fluid by the magnetic separator, recovery separation of a sludge is not fully attained but sludge concentration rises. This leads to raising the sludge concentration in the cutting fluid supplied to the part into which processing with a wire is performed. Consequently, since the cutting force to a wire increases and a wire bends, it is thought that the display flatness of a processing side falls. In addition, if a magnetic separator removes a rare earth alloy sludge appropriately, also except that flatness will improve, even if it does not perform whole-quantity exchange of wire cutting fluid, the effectiveness that prolonged continuous running becomes possible is acquired.
[0106] Since the working efficiency of ****** will fall when [ whole ] the time amount which a next polish process takes is taken into consideration if the flatness of a work-piece cutting plane exceeds 100 micrometers, as for flatness, being set to 15 micrometers or less is desirable, and, also as for magnetism, it is desirable that the flatness of a processing side is adjusted so that it may be set to 15 micrometers or less. For that purpose, it is desirable to set the magnetism in the drum front face of a magnetic separator as 0.27 teslas or more, and it is still more desirable to make it 0.30 teslas or more.
[0107] Again, drawing 1 is referred to. After performing finish-machining by polish to each of the rare earth alloy plate which carried out cutting processing using the above-mentioned approach and preparing a dimension and a configuration, in order to raise long-term dependability, surface treatment is performed to an alloy plate at step S8. After performing a magnetization process by step S9, a neodymium permanent magnet is completed through an inspection process.
[0108] (Example 1) The rare earth alloy was cut using the wire saw equipment shown in drawing 7 . As cutting fluid, the glycol content drainage system cutting fluid (WL-2) by YUSHIRO CHEMICAL INDUSTRY CO., LTD. was used. As a temperature control machine, the automatic temperature control machine (KTC-3B) by Kanto energy machine incorporated company was used. This equipment has the function of both

cooling and heating.

[0109] Moreover, as a wire for cutting, the wire (diameter:of core wire0.18mm, thickness:20micrometer of phenol resin, an abrasive grain quality-of-the-material:diamond, diameter:of abrasive grain40-60micrometer, and average abrasive grain spacing:100micrometer) was used. Both-way transit of this wire was carried out by linear velocity 800 m/min, and equipment was operated on new line amount-of-supply:2 m/min and wire tension:30N conditions. As a cut object, the 20mmx40mmx60mm rare earth alloy was tiered seven, it pasted up, and this was contacted on the wire with the fall velocity of 40 mm/min. Cutting of a rare earth alloy was performed having worked the temperature control machine and maintaining the temperature of cutting oil in the range of 25 degrees C - 28 degrees C under the above-mentioned conditions.

[0110] When the rare earth alloy was deeply cut to 180mm and the cutting plane was observed, profile irregularity Ra is 0.8 micrometers or less, Rmax is 7 micrometers or less, and the smooth field was formed. The cut rare earth alloy fulfilled the quality demanded as a magnet used for the motor for voice coils. Moreover, the amount of deflections of a wire was maintained by abbreviation regularity during cutting, and there was no increment in cutting force.

[0111] (Example 1 of a comparison) Except for not working a temperature control machine, the rare earth alloy was cut like the above-mentioned example 1. Although the temperature of glycol content drainage system cutting fluid was 20 degrees C at the beginning, cutting took for progressing, and went up and it amounted to 50 degrees C or more.

[0112] When the rare earth alloy was deeply cut to 180mm and the cutting plane was observed, profile irregularity is falling, the profile irregularity Ra of a cutting plane is 1.5 micrometers or more, Rmax is 15 micrometers or more as the part cut behind, and the field where irregularity is large was formed. The cut rare earth alloy did not fulfill the quality demanded as a magnet used for the motor for voice coils. Moreover, during cutting, the amount of deflections of a wire increased gradually and the increment in cutting force was accepted.

[0113] As explained above, according to the manufacture approach of the above-mentioned rare earth alloy ****, much advantageous effectiveness as taken below is acquired.

[0114] 1. Since the discharge effectiveness of the cutting fluid from a work-piece cutting plane improves, the cutting force which a wire receives is reduced and the continuation cutting activity of long duration is attained.

[0115] 2. It becomes possible to raise the flatness of a work-piece cutting plane. For this reason, the manufacture yield of a product is improved.

[0116] 3. The effectiveness of wire saw cutting over a rare earth alloy is optimized.

[0117] 4. Since the sludge in cutting fluid is efficiently removable, even if it does not exchange cutting fluid frequently, reduce the cutting load of the wire which wins popularity by the work-piece cutting plane, and it becomes possible to raise cutting speed by it.
[0118] 5. Even if collapse of a work piece arises, it is prevented that the quality of a product deteriorates by contact on a wire.
[0119] In addition, although the operation gestalt of this invention has been explained about the manufacture approach of a rare earth alloy plate, this invention is not limited to this. For example, in order to produce a rare earth alloy product and components with processing configurations other than tabular, the cutting process of this invention can be used suitably.
[0120] Moreover, although the processed object was carried out and the operation gestalt using the rare earth alloy magnet ingredient of Nd-Fe-B was explained, since the property for cutting force to be large and to be easy to condense a sludge is common in the whole rare earth alloy, even if this invention uses other rare earth alloys as a workpiece, it can acquire the effectiveness which described the above-mentioned operation gestalt, and the same effectiveness.
[0121] The rare earth alloy magnet produced using the above-mentioned approach has few cutting margins as compared with the case where a rare earth alloy ingot is cut using a peripheral cutting edge, and is suitable for manufacturing a thin magnet (0.5-3.0mm in for example, thickness). In recent years, since the rare earth magnet used for a voice coil motor is becoming still thinner, if the above-mentioned thin rare earth alloy magnet manufactured using the approach of this invention is attached in a voice coil motor, a small voice coil motor with the high engine performance can be offered.
[0122]
[Effect of the Invention] When it is going to perform cutting processing by the wire saw to a rare earth alloy, as a result of according to this invention preventing a wire piece and also reducing the turnover rate of required cutting fluid remarkably, continuous running of long duration becomes possible.

---

[Translation done.]

---

## TECHNICAL FIELD

---

[Field of the Invention] This invention relates to the cutting process and cutting equipment of a rare earth alloy. It is related with the approach of cutting a rare earth alloy using the wire which made the detail fixing superabrasives, such as a diamond abrasive grain, more.

---

[Translation done.]

THIS PAGE BLANK (USPTO)

---

## PRIOR ART

---

[Description of the Prior Art] Conventionally, in order to cut down many wafers from the ingot of silicon, the technique of using a wire saw and cutting an ingot is developed, for example, it is indicated by JP,6-8234,A. According to such a technique, cutting / cutting processing of an ingot is performed supplying the slurry which contains a grinding abrasive grain to the multi-wire it runs, and it becomes possible to cut down the wafer of fixed thickness to several multi-sheet coincidence.
[0003] The technique which slices an ingot from the former as an approach of cutting the ingot of a rare earth alloy, on the other hand using the slicing blade rotated, for example is known. However, according to the approach of cutting with a slicing blade, since it is large compared with a wire gage, the chipping allowance of thickness of a cutting cutting edge surely increases, and it cannot aim at a deployment of a resource.
[0004] The rare earth alloy is suitably used as for example, a magnet ingredient. Since a magnetic application is diversified and it is widely used also for various kinds of electronic equipment, if the wafer of predetermined thickness is producible from the ingot of a rare earth alloy to several multi-sheet coincidence in few chipping allowances with a wire saw, the manufacturing cost of a rare earth magnet will be reduced sharply.

---

[Translation done.]

---

## EFFECT OF THE INVENTION

---

[Effect of the Invention] When it is going to perform cutting processing by the wire saw to a rare earth alloy, as a result of according to this invention preventing a wire piece and also reducing the turnover rate of required cutting fluid remarkably, continuous running of long duration becomes possible.

---

[Translation done.]

---

## TECHNICAL PROBLEM

---

[Problem(s) to be Solved by the Invention] However, there is still no report that the rare earth alloy was cut using the practical wire saw technique. If it is going to perform cutting processing processing by the loose grain mold wire saw to the ingot of a rare earth alloy, as a result of getting a slurry circulation pipe blocked for a short time extremely for the fines and grinding waste (as ** or a sludge) generated by wire saw processing according to the experiment of artificers, the slurry was no longer supplied on the wire and it turned out that a wire piece will arise. Since it must stop having to interrupt processing by the wire saw at every slurry exchange when the whole slurry is exchanged completely every several hours, in order to avoid this problem, it is not suitable for mass production and utilization becomes impossible. Moreover, the bank and because [ its ] it became empty, cutting force increased also to cutting Mizouchi remarkably, and the sludge also understood much more becoming easy to produce a wire piece. Furthermore, it also turned out during cutting processing processing that phenomena -- a wire carries out a deslot -- occur frequently also into the slot on the roller from the roller with which the bank and the wire to like are twisted, and, as for a sludge, there is a problem that cutting precision falls remarkably. In case each of these problems cuts the ingot of silicon or glass with the conventional wire saw technique, they does not appear.
[0006] Moreover, according to the loose grain mold wire saw of a type which made the abrasive grain float in a slurry, since an abrasive grain rolled at the time of cutting processing, there was also a problem that improvement in the amount of cutting per unit time amount (cutting speed) was difficult. Especially, a rare earth alloy is hard compared with silicon or glass, and it is sticky, and since it is the ingredient which is hard to cut, when a rare earth alloy is cut using a loose grain mold wire saw, cutting speed becomes quite slow.
[0007] JP,8-126953,A is indicating the technique of cutting a silicon ingot by making water into a coolant, using the wire which has bonded abrasive. However, if this

technique is used for cutting of a rare earth alloy, since eccr[illegible] is bad, the same problem as the case where it is a loose grain will produce the sludge of a rare earth alloy.
[0008] This invention is made in view of these many points, and the main purpose is to offer the cutting process of the rare earth alloy which can raise cutting speed while it prevents a wire piece and makes prolonged continuous running possible.
[0009] Moreover, other purposes of this invention are to offer the voice coil motor equipped with the manufacture approach of a rare earth alloy magnet of having used the cutting process of the above-mentioned rare earth alloy, and the rare earth alloy magnet concerned.

---

[Translation done.]

THIS PAGE BLANK (USPTO)

---

MEANS

---

[Means for Solving the Problem] The cutting process of the rare earth alloy of this invention is the cutting process of the rare earth alloy using the wire which made the abrasive grain fix, and while the surface tension in 25 degrees C supplies the drainage system cutting fluid which is within the limits of 33 mN/m - 49 mN/m between said wires and said rare earth alloys, it is characterized by cutting said rare earth alloy.
[0011] As said drainage system cutting fluid, the thing containing a glycol can be used suitably.
[0012] Or the thing containing synthetic lubricant can also be used as said drainage system cutting fluid.
[0013] Said drainage system cutting fluid may also contain a defoaming agent. Moreover, as for said drainage system cutting fluid, it is desirable that PHs are 9-11. Said drainage system cutting fluid may also contain a rusr-proofer.
[0014] What contains the abrasive grain made to fix with phenol resin as said wire can be used suitably. As an abrasive grain, a diamond abrasive grain is used suitably.
[0015] It is desirable to include the process which controls the temperature of said drainage system cutting fluid.
[0016] It is desirable to include further the process which collects the drainage system cutting fluid containing the sludge of said rare earth alloy produced when cutting said rare earth alloy, and the process which removes a sludge from said collected drainage system cutting fluid before controlling the temperature of said drainage system cutting fluid.
[0017] The process which controls the temperature of said drainage system cutting fluid includes the process which mixes the process which adjusts the temperature of some drainage system cutting fluid from which the sludge was removed, and some [ by which said temperature was adjusted ] drainage system cutting fluid and the remaining drainage system cutting fluid with which temperature is not adjusted, and you may make it supply

THIS PAGE BLANK (USPTO)

said mixed drainage system cutting fluid between said wires and said rare earth alloys.
[0018] You may make it magnetism separate the sludge of said rare earth alloy produced when cutting said rare earth alloy from the inside of said drainage system cutting fluid.
[0019] It is desirable to use the magnetic separator which shows the magnetism of 0.27 teslas or more in the field which collects said sludges.
[0020] Two or more ring-like slots are formed in a periphery in a predetermined pitch, and cutting process of the aforementioned rare earth alloy can be suitably performed using wire saw equipment equipped with two or more rollers supported pivotable and the driving means which makes it run said wire twisted around said slot of said roller while rotating said roller.
[0021] It is desirable to cut said rare earth alloy, going caudad from the upper part and dropping said rare earth alloy to said wire.
[0022] It holds, where said rare earth alloy is divided into two or more blocks, and it may be made to perform a part of supply [ at least ] of said drainage system cutting fluid through the gap of a block of said plurality. Or you may carry out by making it run said wire in said cutting fluid to which supply of said cutting fluid is supplied from opening of a cutting fluid tub.
[0023] The manufacture approach of the rare earth alloy plate by this invention is characterized by including the process which produces the ingot of a rare earth alloy, and the process which separates two or more rare earth alloy plates from the ingot of said rare earth alloy using the cutting process of an above-mentioned rare earth alloy.
[0024] The manufacture approach of the rare earth alloy magnet by this invention is characterized by including the process which produces a sintered compact from rare earth magnet alloy powder, and the process which separates two or more rare earth alloy magnets from said sintered compact using the cutting process of an above-mentioned rare earth alloy.
[0025] The voice coil motor by this invention is characterized by having the rare earth alloy magnet produced by the manufacture approach of said rare earth alloy magnet.
[0026] The thickness of said rare earth alloy magnet may be in the range of 0.5-3.0mm.
[0027]
[Embodiment of the Invention] The invention-in-this-application person cut the rare earth alloy using the wire which made the abrasive grain fix for the purpose which raises cutting speed. Since ** of the abrasive grain at the time of cutting can prevent ** by fixing an abrasive grain to a wire, cutting speed improves. When based on this approach, the slurry for making an abrasive grain float becomes unnecessary, but in order to flush a sludge from the cutting section (it discharges), it is necessary to fully supply cutting fluid to a cutting processing part. According to the experiment of this invention person, when water (tap water) was used as cutting fluid, it turned out that cutting force increases [ the

THIS PAGE BLANK (USPTO)

sludge of a rare earth alloy to cutting Mizouchi remarkably because [ its ] it becomes empty, the bank and, and it becomes easy to produce a wire piece. Also in the case of a loose grain mold, such a phenomenon is seen as mentioned above. However, since the amount of the sludge shaved [ rare earth alloy / which is a candidate for cutting ] by unit time amount increases when using the wire which made the abrasive grain fix, increase of cutting force poses a bigger problem.
[0028] Moreover, when a rare earth alloy was cut using water as cutting fluid, the wear of a wire which has bonded abrasive was intense, and as a result of the cutting capacity of a wire declining between short time, it turned out that cutting speed falls greatly. Since a rare earth alloy is an ingredient with stickiness it is hard and high, its friction produced between a wire and a rare earth alloy at the time of cutting is large. When cutting a rare earth alloy, using water as cutting fluid, it is thought that this friction cannot fully be reduced. When this also cut the ingot of silicon with easier cutting than a rare earth alloy, or glass, it had not become a big problem, either.
[0029] Moreover, if the condensed sludge checks circulation of cutting fluid within the cutting fluid circulation pipe in wire saw equipment, since a cutting fluid circulation pipe will be got blocked by it, unless cutting fluid is exchanged frequently, it becomes impossible to carry out continuous running of long duration. It is thought that it is produced since precipitate and condensation of a sludge have the large specific gravity of the iron which constitutes a rare earth alloy, and rare earth elements. When the ingot of silicon or quartz glass was cut using a wire saw, the sludge was promptly flushed with cutting fluid, precipitate and condensation of a sludge were hardly produced, and especially the big problem resulting from that was not generated until now.
[0030] this invention person found out that cutting force could be reduced by using the drainage system cutting fluid which has the surface tension of the predetermined range instead of using water as cutting fluid. As for the surface tension in 25 degrees C of drainage system cutting fluid, it is desirable that it is within the limits of 33 mN/m - 49 mN/m so that it may mention later. Since the permeability (wettability or concordance) over the cutting edge containing a diamond system abrasive grain is excellent compared with water, the drainage system cutting fluid which has the above-mentioned surface tension within the limits is considered for drainage system cutting fluid to permeate efficiently the cutting section (part by which a rare earth alloy and a cutting edge contact and a rare earth alloy is cut). In addition, the surface tension of cutting fluid is measured using the DEYUNUI surface tension balance known well. Moreover, since water is used as a principal component and the specific heat is generally large compared with cutting oil (straight mineral oil is included typically), drainage system cutting fluid is excellent in cooling effectiveness. Furthermore, there is also an advantage which can prevent having a bad influence on natural environment by abandonment processing of cutting fluid.

THIS PAGE BLANK (USPTO)

[0031] Although the drainage system cutting fluid used by the cutting approach of this invention was specified using the surface tension of 25 degrees C, the temperature of the drainage system cutting fluid at the time of actually using it is not restricted to 25 degrees C. However, in order to acquire the effectiveness of this invention, it is desirable to use the drainage system cutting fluid by which temperature control was carried out within the limits of 15 degrees C - 35 degrees C. For example, in early stages, when using it, circulating cutting fluid, the temperature of the cutting fluid supplied at the comparatively low temperature of room temperature extent rises with steps, when cutting fluid absorbs the frictional heat generated between a wire and a rare earth alloy. While using it, circulating cutting fluid, the temperature of cutting fluid can exceed about 50 degrees C. Since it depends for the surface tension of a liquid on temperature as known well, if it separates not much from the temperature requirement of the above [ the temperature of the actually used drainage system cutting fluid ], the surface tension of drainage system cutting fluid will be in the condition of having resembled well the condition of having separated from the above-mentioned numerical range, and a cutting efficiency will fall.
[0032] The surface tension of drainage system cutting fluid can be easily adjusted within the limits of the above by adjusting a glycol (a glycol derivative being included), and the class and amount of a surfactant to add. The surface tension of the above-mentioned range can also be obtained by replacing with these and adding in water the so-called synthetic lubricant called "synthetic [ synthetic (Synthetic) ]." These can also be mixed and used.
[0033] When water is used as cutting fluid, it is thought that above-mentioned fault occurred in the following reasons.
[0034] The width of face of the cutting slot formed in a rare earth alloy with a wire is narrow (for example, 0.3mm or less) one, and it is difficult to supply direct cutting fluid to a cutting slot, and cutting fluid is supplied to a wire and supplied to cutting Mizouchi in the condition of having made it adhering to a wire. If the wettability to the wire of the cutting fluid supplied by such approach is low, it will become easy to be desorbed from a wire, sufficient amount will no longer be supplied to cutting Mizouchi, and the effectiveness of cutting fluid will fall. Furthermore, the permeability to the cutting edge of cutting fluid also falls.
[0035] That is, the cutting fluid of sufficient amount for cutting Mizouchi is not supplied, but if the permeability to a cutting edge is low, it will increase, a cutting efficiency will fall, possibility that a wire piece will be generated will become high, and cutting force will also produce the problem that the process tolerance of the cutting plane of a rare earth magnet falls further. Moreover, cutting force increases by the sludge which eccritic [ of a sludge ] fell, and the sludge of a rare earth alloy with large specific gravity became that it is hard to be discharged from a cutting slot, consequently accumulated in

Mizouchi. Since it is hard compared with sludges, such as silicon, when a sludge is not discharged, cutting force will increase the sludge of a rare earth alloy remarkably. Moreover, a wire cannot fully be cooled, but the temperature of a wire carries out an abnormality rise, the anomalous attrition of a wire and abnormality degraining of an abrasive grain (typically diamond system abrasive grain) arise, and a cutting efficiency and process tolerance fall.

[0036] The drainage system cutting fluid which has the surface tension of the above-mentioned range has moderate wettability to a wire (and rare earth alloy), and is fully supplied to a narrow cutting slot. Moreover, also when using it, having circulated cutting fluid and continuous running is performed over a long time by adjusting the temperature of cutting fluid, while being able to maintain cutting fluid to the temperature of the predetermined range, the surface tension of cutting fluid is always controllable within the limits of a request. It becomes possible to prevent the increment in cutting force and to cut a rare earth alloy with a sufficient precision efficiently by this. In addition, since the lubricity and viscosity (kinematic viscosity) of cutting fluid also influence cutting-ability ability, the range of the desirable surface tension of cutting fluid may change somewhat with classes of cutting fluid to be used.

[0037] In addition, especially the viscosity of cutting fluid influences eccritic [ of a sludge ]. Although the kinematic viscosity of drainage system cutting fluid is generally low compared with cutting oil, and the kinematic viscosity of drainage system cutting fluid other than a glycol system is not based on temperature but it is about 1mm2/s, the kinematic viscosity of the cutting fluid containing a glycol is comparatively high, and its temperature dependence is also large. Since it may become that a cutting slot is fully hard to be supplied even if it has the surface tension of the above-mentioned range when kinematic viscosity exceeds 67mm2/s, as for the kinematic viscosity of the cutting fluid supplied between a wire and a rare earth alloy, it is desirable that it is less than [ 67mm2/s ]. Of course, it is desirable that the temperature of cutting fluid is within the limits of 15 to 35 degrees C also in this case. Furthermore, as for the temperature of cutting fluid, it is desirable that it is within the limits of 20 to 25 degrees C.

[0038] Moreover, since viscosity is comparatively low, drainage system cutting fluid can classify rare earth alloy waste from the sludge generated by cutting easily using a magnet, and can reuse drainage system cutting fluid. For example, when carrying out the cyclic use of waste water of the drainage system cutting fluid, while preventing plugging within the circulation pipe of cutting fluid, frequent exchange of cutting fluid can be made almost unnecessary, and a run length can be remarkably improved as compared with the conventional technique. Moreover, it can prevent having a bad influence on natural environment by abandonment processing of drainage system cutting fluid. In addition, since the time amount by which a rare earth alloy is put to drainage system cutting fluid

THIS PAGE BLANK (USPTO)

is comparatively short, the property of a rare earth alloy does not deteriorate by oxidation in the meantime.

[0039] The travel speed of a wire is quick (a part for for example, thousands of part [ for hundreds of m/- ], and m/) one, drainage system cutting fluid may foam at it, and cooling effectiveness may fall. By using the drainage system cutting fluid containing a defoaming agent, decline in the cooling effectiveness by foaming of drainage system cutting fluid can be controlled. Furthermore, the corrosion of a rare earth alloy can be controlled by using the drainage system cutting fluid which has PH within the limits of 9-11. Moreover, oxidation of a rare earth alloy can be controlled by using the drainage system cutting fluid containing a rusr-proofer. What is necessary is just to adjust these suitably in consideration of a class, processing conditions, etc. of a rare earth alloy.

[0040] (Operation gestalt) The operation gestalt of the manufacture approach of the rare earth alloy plate by this invention is explained hereafter. With this operation gestalt, what permuted a part of Nd of compound Nd-Fe-B of the ternary system which uses neodymium (Nd), iron (Fe), and boron (B) as a principal component as a rare earth alloy, or Nd-Fe-B by Dy (dysprosium), and permuted a part of Fe by Co (cobalt) is used. Nd-Fe-B is known as a powerful neodymium magnet ingredient with which a maximum energy product exceeds 320 kJ/m3.

[0041] How to produce the ingot of Nd-Fe-B is explained briefly, referring to the flow chart of drawing 1 . In addition, the approach of producing the rare earth alloy as a magnet ingredient is indicated by for example, the U.S. Pat. No. 4,770,723 specification at the detail.

[0042] First, after carrying out weighing capacity of the raw material to a predetermined component ratio correctly at step S1 of drawing 1 , a raw material is dissolved with the RF fusion furnace of a vacuum or an argon gas ambient atmosphere at step S2. The dissolved raw material is cast to water-cooled mold, and the raw material alloy of a predetermined presentation is formed. A raw material alloy is ground at step S3, and impalpable powder with a mean particle diameter of about 3-4 micrometers is produced. Impalpable powder is put into metal mold by step S4, and press forming is carried out in a field. Press forming is performed after mixing impalpable powder with lubricant if needed at this time. Next, if an about about 1000-1200-degree C sintering process is performed at step S5, a neodymium magnet material is producible. Then, in order to raise magnetic coercive force at step S6, about 600-degree C aging treatment is performed, and production of a rare earth alloy ingot is completed. The size of an ingot is 30mmx50mmx60mm.

[0043] At step S7, cutting processing of a rare earth alloy ingot is performed, and two or more sheet metal (called a substrate or a wafer) cut from the ingot is formed. Before giving explanation after step S8, how to carry out cutting processing of the ingot of a rare

earth alloy with the wire saw technique by this invention in the following is explained to a detail.
[0044] Drawing 2 (a) and (b) are referred to. First, it fixes mutually with the adhesives 22 which consist of an epoxy resin, and two or more ingots 20 produced by the above-mentioned approach are fixed to the work-piece plate 26 iron in the condition of having assembled as two or more blocks 24a-24c. Fixing between the work-piece plate 26 and each blocks 24a-24c is also attained by adhesives 22. In the detail, the base plate 28 made from carbon which functions as a dummy has been arranged more between the work-piece plate 26 and each blocks 24a-24c, and this base plate 28 made from carbon has also fixed through adhesives 22 to the work-piece plate 26 and each blocks 24a-24c. After cutting processing of Blocks 24a-24c is completed, the base plate 28 made from carbon receives cutting processing by the wire saw until downward actuation of the work-piece plate 26 stops, and is bearing a role of a dummy of protecting the work-piece plate 26.
[0045] With this operation gestalt, each block size is designed so that the size of each blocks 24a-24c measured along the direction (the "wire transit direction" is called below) shown by the arrow head A of drawing 2 (a) may be set to about 100mm. Since the size measured along the wire transit direction about one ingot 20 is about 50mm, he is trying to constitute each of the above-mentioned blocks 24a-24c from this operation gestalt by piling up what arranged the ingot 20 whose number is two along the wire transit direction.
[0046] Although two or more ingots 20 fixed to the work-piece plate 26 are called a "work piece" as a whole, the following advantages are born by dividing this work piece into two or more blocks.
[0047] When the wire transit direction size (the die length of a cutting slot) becomes large too much about the work piece of 1 padding exceeding the amount of drawing in of cutting fluid, the field where cutting fluid supply becomes inadequate among the cutting processing parts of a work piece occurs, and there is a possibility that a wire open circuit may arise by this. However, since the work piece of this operation gestalt is divided into the blocks 24a-24c of suitable size, it becomes possible to supply cutting fluid to the clearance between Blocks 24a-24c, and it can solve the problem that cutting fluid supply is insufficient. Moreover, since the sludge which accumulated between abrasive grains can also be flushed by this, cutting efficiency also improves.
[0048] In order to supply cutting fluid to the clearance between Blocks 24a-24c, he arranges two cutting fluid delivery pipes 29 in the upper part of the work-piece plate 28, and is trying to inject fresh cutting fluid downward out of the cutting fluid delivery pipe 29 through slit-like nozzle 29a with this operation gestalt. The cutting fluid delivery pipe 29 receives the cutting fluid with which the fresh cutting fluid which does not contain a sludge, or a sludge was removed from the cutting fluid service tank mentioned later. The

cutting fluid delivery pipe 29 has the structure of a double tube type, and the width of face of downward slit 29a changes to a longitudinal direction, and it is designed so that uniform cutting fluid supply may be realized.
[0049] Although the work piece is divided into two or more blocks as mentioned above with this operation gestalt, as what magnitude the wire transit direction size about each of each blocks 24a-24c should be set changes also with the surface tension and the wire travel speeds of cutting fluid. Moreover, the number of ingots 20 and arrangement which constitute one block also change with the magnitude of each ingot 20. What is necessary is just to divide a work piece into the block of the optimal size suitably in consideration of these. Moreover, although the cutting fluid delivery pipe 29 is formed in the work-piece plate 26 bottom, you may make it supply cutting fluid between blocks with the work-piece plate 26 down side in this operation gestalt.
[0050] Next, the principal part 30 of the wire saw equipment suitably used with this operation gestalt is explained, referring to drawing 3 A and drawing 3 B. This wire saw equipment is equipped with three Maine rollers 34a-34c with which one wire 32 is twisted also around many [-fold ]. Among these, although two Maine rollers 34a and 34b are supported free [ rotation ] by wire saw equipment, it does not connect with the driving means of a motor etc. directly, but they function on it as a follower roller. On the other hand, it connects with the non-illustrated driving source, for example, motor, and by this driving source, Maine roller 34c can receive a desired turning effort, and can be rotated at a setting rate. Maine roller 34c functions as a driving roller in order to transmit turning effort to two Maine rollers 34a and 34b through a wire 32.
[0051] A wire 32 is guided receiving the tension of several kg-wt according to rotation of the Maine rollers 34a-34c, and it is rolled round from the non-illustrated reel by the reel which is not illustrated [ other ], carrying out both-way transit at a predetermined rate (a part for for example, 600-1000m/).
[0052] Two or more slots are formed in the periphery front face of the Maine rollers 34a-34c at equal intervals, and as one wire 32 is inserted in much Mizouchi, it is twisted around each roller. The array pitch (spacing of a wire train) of a wire 32 is prescribed by the pitch of this slot. With this operation gestalt, this pitch is set as about 2.0mm. Since this pitch is set up according to the thickness of the sheet metal which should be cut down by cutting processing, it will choose and use the multi-slot rollers 34a-34c which had a suitable pitch suitably.
[0053] A wire 32 is formed from a hard drawn steel wire (piano wire), and, as for the size, an about 0.06-0.25mm thing is used. The cross-section configuration of a wire is shown in drawing 6 . In the front face of the wire core wire 61 used with this operation gestalt, the diamond abrasive grain 62 whose particle size is 30-60 micrometers has fixed with the resin film 63 so that drawing 6 may show. The resin film 63 is formed from

THIS PAGE BLANK (USPTO)

phenol resin etc., and the thickness is 30-60 micrometers. As for spacing of abrasive grain 62 in the condition of having fixed, it is desirable that it is about 2 to 4 times the diameter of an abrasive grain 62. Moreover, it can replace with the resin film 63 and the diamond abrasive grain 62 can also be fixed by metal membranes, such as nickel.

[0054] In addition, the wire core wire 61 may be formed from what bundled refractory metals, such as alloys, such as nickel-Cr and Fe-nickel, W, and Mo, or nylon fiber. Moreover, the ingredient of an abrasive grain may not be limited to a diamond, but may be SiC, B, C, CBN (Cubic BoronNitride), etc.

[0055] A work piece is pressed against the part stretched and passed between Maine roller 34a and Maine roller 34b among the wires 32 it runs on the occasion of cutting processing processing. With this operation gestalt, cutting fluid can be supplied on a wire 32 from at least three places, and cutting fluid supply from two places is performed using the clearance between blocks using the pipe 29 and slit-like nozzle 29a which have been arranged in the upper part of the work-piece plate 26 among those. Cutting fluid supply from remaining one place is performed using a nozzle 36 in drawing 3 B from the left-hand side of a work piece. In addition to these nozzles 29a and 36, supply of cutting fluid may be additionally performed from the location on the right-hand side of a work piece in drawing 3 B, using other nozzles.

[0056] Furthermore, like [ the case where cutting fluid especially with low viscosity is used, and when the travel speed of a wire 32 is quick (a part for for example, 1000m/above) ], when it is hard to supply cutting fluid to a wire 32, as shown in drawing 3 B, cutting fluid can be more certainly supplied to a wire 32 by making it run the inside of the cutting fluid supplied by overflowing from cutting fluid tub 38 opening in a wire 32 (for example, refer to JP,11-198020,A).

[0057] With this operation gestalt, surface tension supplies the drainage system cutting fluid of 33 mN/m - 49 mN/m within the limits between a work piece and a wire. The width of face of the cutting slot formed in a work piece is very as narrow as about 0.3mm or less typically, and it is difficult to supply cutting fluid to a cutting slot directly. For this reason, cutting fluid is supplied to a wire, Mizouchi is made to draw this and it is made to discharge out of a slot after that with a wire. Thus, if the surface tension supplied is lower than 33 mN/m or higher than 49 mN/m, the wettability to a wire will be bad, and will not be supplied in sufficient quantity of a cutting fluid fang furrow, the sludge formed from a rare earth alloy with large specific gravity will become that it is hard to be discharged from a cutting slot, consequently cutting force will go up. Moreover, if sufficient quantity of cutting fluid is not supplied to cutting Mizouchi, lubricity sufficient between a wire and a rare earth alloy will not be obtained (sharpness falls), but the field roughness and dimensional accuracy of a cutting plane will worsen. Moreover, it is not controlled in the range where coefficient of friction of a cutting edge is proper, consequently the

anomalous attrition of an abrasive grain happens, and the problem that the abrasiveness of a wire becomes high is also produced. Consequently, the life of a wire becomes short while cutting efficiency falls greatly.
[0058] On the other hand, if the drainage system cutting fluid which has the surface tension of above-mentioned within the limits is used, since it will be supplied in sufficient quantity of a cutting fluid fang furrow, promptly, the sludge (namely, rare earth alloy powder with large specific gravity (the specific gravity of for example, a neodymium alloy is about 7.5)) produced in cutting Mizouchi of a rare earth alloy is flow, and is eliminated from a cutting field in the exterior of a cutting slot (high discharge effectiveness). For this reason, the wire piece by the increment in cutting force and the problem of a cutting efficiency fall can be solved, without the sludge which accumulated in cutting Mizouchi barring transit of a wire strongly. Moreover, it is controlled in the range where coefficient of friction in a cutting edge is also proper. Furthermore, since the specific heat is high compared with cutting oil, drainage system cutting fluid is excellent also in cooling effectiveness, and can control and prevent the abnormality rise of the temperature by friction efficiently. Moreover, since viscosity is comparatively low, the amount of the sludge carried by even the Maine roller with the wire it runs is also reduced, and drainage system cutting fluid can also control the phenomenon in which a sludge accumulates in Mizouchi on the Maine roller. Consequently, a wire piece is prevented and there is also an advantage that a wire can be easily removed from a work piece after work-piece cutting termination.
[0059] As drainage system cutting fluid, glycol system cutting fluid (YUSHIRO CHEMICAL INDUSTRY [ CO., LTD. ] make: WL-2) can be used, for example. With the class and molecular weight of the glycol to be used, the drainage system cutting fluid of desired surface tension can be prepared by adjusting the addition to water.
[0060] Moreover, the cutting fluid which added the surfactant can also be used for water. As a surfactant, ARUKI roll amide systems, such as polyhydric-alcohol systems, such as polyoxyethylene systems, such as polyoxyethylene alkyl phenyl ether and polyoxyethylene mono-fatty acid ester, and sorbitan mono-fatty acid ester, or fatty-acid diethanolamide, can be used as an anion system as sulfonic acid types, such as sulfate molds, such as fatty-acid derivatives, such as fatty-acid soap and naphthenic-acid soap, or a long-chain alcoholic sulfate, and sulfated oil of animal and vegetable oils, or a petroleum sulfonate, and a non-ion system. Specifically, surface tension can be adjusted within suitable limits by adding chemical solution type JP-0497N (castrol company make) about 2% of the weight in water.
[0061] Furthermore, the cutting fluid which added synthetic lubricant can also be used for water. As synthetic type composition lubricant, a synthetic solution type, a synthetic emulsion type, and a synthetic soluble type can be used, and also in it, a synthetic

THIS PAGE BLANK (USPTO)

solution type is desirable a[illegible], specifically, can mention SH[illegible]AIRO#870 [ 9954 (castrol company make) ] (YUSHIRO CHEMICAL INDUSTRY CO., LTD. make). All can adjust surface tension within suitable limits by adding about 2% of the weight in water.
[0062] Moreover, the corrosion of a rare earth alloy can be prevented by making cutting fluid contain a rust preventive. Here, as for PH, being referred to as 9-11 is desirable. As a rust preventive, a phosphoric acid salt, a borate, molybdate, a tungstate, or a carbonate can be used as amines, such as carboxylate, such as oleate and a benzoate, or triethanolamine, and an inorganic system as an organic system.
[0063] Moreover, nitrides, such as bends triazole, can be used as nonferrous metal anticorrosives, and formaldehyde donators, such as hexa hydro triazine, can be used as antiseptics, for example.
[0064] Moreover, a silicone emulsion can be used as a defoaming agent. By making a defoaming agent contain, foaming of cutting fluid is lessened, the permeability to the cutting slot on the cutting fluid is improved, the cooling effect increases, and an abnormality rise and anomalous attrition of the temperature of a wire 32 stop being able to happen easily.
[0065] Such drainage system cutting fluid cannot pollute an environment easily compared with non-water solubility cutting fluid (oil). Moreover, the danger of emitting smoke and ignition is safe for drainage system cutting fluid few, and if drainage system cutting fluid is used, work environment is improvable, since an oil mist is not generated. Furthermore, since it is easy to remove a sludge, drainage system cutting fluid is also an ingredient suitable for a reuse (cyclic use of waste water).
[0066] Drawing 3 B is referred to. On the occasion of cutting processing processing of a work piece, the work-piece plate 26 is moved along with an arrow head D downward at the rate of predetermined (a part for for example, 0.5-1.0mm/) by the non-illustrated driving gear, and pushes the work piece fixed to the work-piece plate 26 against the wire 32 it runs in a level longitudinal direction (the direction of arrow-head A). By supplying the cutting fluid of amount sufficient between a work piece and a wire 32, a sludge can be discharged from between a work piece and wires 32, and a work piece can be continuously cut by it. Although cutting efficiency will improve if fall velocity of the work-piece plate 26 is made quick, since cutting force goes up, the flapping phenomenon of a wire 32 occurs, and there is a possibility that the flatness of a work-piece cutting plane may worsen. Flatness degradation of a work-piece cutting plane increases the time amount which a polish activity at a next process takes, or makes the probability of occurrence of a defective increase. Therefore, it will be necessary to set up the fall velocity of a work piece, i.e., the cutting speed of a work piece, within suitable limits.
[0067] The wire 32 arranged at constant pitch carries out grinding of the work piece as a multi-wire saw, the channel depth is increased, carrying out coincidence formation of

THIS PAGE BLANK (USPTO)

many processing slots (cutting slot) in connection with it at a work piece, and cutting processing is made to advance by descent of a work piece. When a processing slot crosses each ingot completely, cutting processing of the ingot is attained and many wafers of the thickness decided by the pitch of a wire train and the size of a wire are cut down by coincidence. After cutting of all the ingots 20 is completed, the work-piece plate 26 is raised along with an arrow head D by the above-mentioned driving gear. Then, while each block is separated from the work-piece plate 26, the cut wafer will be separated from each block.

[0068] With this operation gestalt, in order to perform cutting processing, dropping a work piece from the upper part of a wire 32, the work-piece plate 26 descends with the condition of having combined with the work-piece plate 26 still more the ingot 20 which received cutting processing with adhesives. Thus, since it is located under the wire, even if the part of a work piece processed [ cutting ] dissociates and falls out from the body of a work piece, there is no possibility of 20 ingot which received cutting processing that the omission part may contact a wire 32 again. Therefore, an alloy plate [ finishing / cutting processing ] will be turned to the following process in the state of high quality.

[0069] Next, the outline configuration of the cutting fluid circulation system of wire saw equipment 40 is explained, referring to drawing 4 . As typically shown in drawing 4 , while supplying cutting fluid to the principal part 30 of wire saw equipment, in equipment 40, the cutting fluid circulation system for collecting the used cutting fluid containing the sludge formed of processing is prepared.

[0070] In the case of this equipment 40, on the occasion of cutting processing of a work piece, cutting fluid is supplied to the cutting fluid delivery pipe 29 on the work-piece plate 26 shown in drawing 3 A and drawing 3 B and a nozzle 36, or the cutting fluid tub 38 of drawing 3 C through the 1st circulation pipe 44 from the cutting fluid service tank 42. A pump P1 is used at this time. The cutting fluid used for cutting processing is dropped from a processing part and its circumference, and is received by the recovery drain 37 located caudad and its processing machine drain 37' prepared caudad. Cutting fluid is carried to ****** 54 through the 2nd circulation pipe 46 from the recovery drain 37 and processing machine drain 37', and after it receives the sludge separation processing by the magnetic separator 50 mentioned later there, it is accumulated in the recovery tank 48. The cutting fluid which returned to the condition near the condition before cutting processing is sent to the cutting fluid service tank 42 through the 3rd circulation pipe 49 by this sludge separation processing. A relay pump P2 is used at this time. Filter F is inserted in the middle of the 3rd circulation pipe 49, and Filter F can remove the sludge which was not removed by the magnetic separator 50. As a filter F, a saccate bag filter is used suitably.

[0071] In addition, the cutting fluid service tank 42 can settle the detailed sludge which

might penetrate Filter F. For this reason, it is possible to reduce further the amount of the sludge which remains in the cutting fluid sent to the principal part 30 through the 1st circulation pipe 44. At this time, since the magnetic separator 50 is magnetized, it condenses and a detailed sludge is easy to precipitate by it.

[0072] Thus, with this operation gestalt, in order to perform separation removal (filtering) of a sludge efficiently, performing supply and recovery of cutting fluid cyclically, it enables it to prolong spacing of a cutting fluid exchange activity remarkably, and to continue cutting processing processing continuously over long duration. In addition, in order to maintain the surface tension of cutting fluid to request within the limits, water or new cutting fluid may be supplied with a suitable time interval. In this case, when surface tension of cutting fluid is surveyed periodically and surface tension separates out of a setting range, you may make it supply water or new cutting fluid in equipment (for example, cutting fluid service tank 42) at any time. Partial supply of such cutting fluid differs from whole-quantity-exchange of cutting oil greatly at the point which can be performed without interrupting cutting processing processing.

[0073] Next, a magnetic separator 50 is explained, referring to drawing 5 . This magnetic separator 50 can separate a sludge from the separation tub 54 which stored the used cutting fluid (dirty liquid) 52 containing a sludge using magnetism. Separation wall 54a is prepared in the separation tub 54. This separation wall 54a has the function to make a big sludge sediment to the separation tub 54. The fine sludge which was able to float in dirty liquid 52 and was able to overcome separation wall 54a with dirty liquid 52 will be magnetically separated by the approach of explaining in full detail below.

[0074] The magnetic separator 50 is equipped with the drum 56 on which the powerful magnet has been arranged inside, and the squeezing roller 57 which rotates while sticking to a part of peripheral face of a drum 56. Being supported pivotable centering on a fixed shaft, the drum 56 is arranged so that cutting fluid 52 may be partially contacted within the separation tub 54. The squeezing roller 57 is formed from oil resistant rubber etc., and a pressure welding is carried out by the energization force of a spring to the peripheral face of a drum 56. If a drum 56 rotates in the direction of an arrow head by the non-illustrated motor, the rotation will give frictional force to a squeezing roller 57, and will carry out the rotation drive of the squeezing roller 57.

[0075] The sludge which floats in cutting fluid 52 sticks to the peripheral face of the rotating drum 56 with the magnet in a drum 56. The sludge which stuck to the peripheral face of a drum 56 is removed out of cutting fluid 52 with rotation of a drum 56, and passes through between a drum 56 and squeezing rollers 57. Soon, by the scraper 58, a sludge is scratched from the front face of a drum 56, and are collected in the sludge box 59. Thus, the cutting fluid from which the sludge was removed is carried by the recovery tank 48 with a pipe 60 from the edge in the longitudinal direction of a drum 56. The

THIS PAGE BLANK (USPTO)

structure of a desludging means usable as such a magnetic separator 50 is indicated by JP,63-23962,Y. According to the experiment of the artificer who explains later, in order to draw near to the front face of a drum 56 the sludge of the rare earth alloy in cutting fluid, it is desirable to make the magnetism in the peripheral face (sludge recovery side) of the drum 56 in cutting fluid 52 into 0.27 teslas or more, and it is still more desirable to make it 0.3 teslas or more. By having used drainage system cutting fluid with low viscosity, the advantage of making easy recovery of the rare earth alloy sludge by the magnetic separator 50 can also be acquired. It is because the viscous drag which the sludge which moves in the inside of the field formed into cutting fluid 52 receives is reduced, so it becomes possible to collect many sludges efficiently.

[0076] If a sludge is efficiently removed using such a separator, since the sludge which can maintain low the concentration of the sludge contained in the cutting fluid by which the cyclic use of waste water is carried out, and is supplied to a cutting edge with cutting fluid can be lessened, the cutting load which a wire receives can be maintained at level small enough over a long period of time by the work-piece cutting plane.

[0077] Hereafter, the configuration of the cutting fluid circulation system 70 of another gestalt equipped with the temperature control machine is explained, referring to drawing 7 and drawing 8 . In addition, the same reference mark is attached about the part which has the same configuration to the circulation system shown in above-mentioned drawing 4 and drawing 5 . Below, the part which has a different configuration from the circulation system shown in above-mentioned drawing 4 and drawing 5 is mainly explained.

[0078] In the cutting fluid circulation system 70 shown in drawing 7 , cutting fluid is supplied to the principal part 30 of wire saw equipment through the 1st circulation pipe 76 on the occasion of cutting processing of a work piece from a purge 72. The dirty liquid received on the other hand by the recovery drain 37 and processing machine drain 37' which were prepared in the principal part 30 is carried by the purge 72 through the 2nd circulation pipe 78, and after it receives the sludge separation processing by an above-mentioned magnetic separator 50 and an above-mentioned bag filter 84 there, it is accumulated in the recovery tank 48 (the separation tub 82 and temperature control tub 92).

[0079] On the whole in the principal part 30, the temperature of the cutting fluid which circulates through a circulation system 70 rises by absorbing the frictional heat generated between a wire and a rare earth magnet. A rise of the temperature of cutting fluid will increase the cutting force in cutting by the short supply to the cutting slot of the cutting fluid resulting from the surface tension of cutting fluid, and decline in cooling effectiveness. On the other hand, in a circulation system 70, the temperature of the cutting fluid by which the cyclic use of waste water is carried out is maintainable in a predetermined temperature requirement using the temperature control machine 74

THIS PAGE BLANK (USPTO)

connected to the purge 72. As a temperature control machine 74, the well-known temperature control machines (for example, temperature controller given in JP,8-25125,B etc.) equipped with the heat exchanger etc. could be used, and the temperature control machine 74 is preferably equipped with both the cooling function and the heating function.

[0080] The temperature control machine 74 is controlled to operate, when the temperature of cutting fluid rises exceeding a predetermined value, and can control the temperature of the cutting fluid supplied to the principal part 30 to predetermined within the limits. Thus, if temperature control of cutting fluid is performed, since it will maintain the surface tension of the cutting fluid supplied between a wire and a rare earth magnet within suitable limits and cutting force will not be made to increase, cutting fluid cannot be exchanged but ** can also perform cutting of a rare earth magnet continuously.

[0081] Next, the configuration of a purge 72 is explained, referring to drawing 8 . This purge 72 consists of the separation section 80 equipped with an above-mentioned magnetic separator 50 and the above-mentioned separation tub 82, and a temperature controller 90 equipped with the temperature control tub 92. The separation tub 82 and the temperature control tub 92 are separated by the septum 88, and a septum 88 prevents that cutting fluid moves freely between tubs. In the upper part of a septum 88, free passage section 88a (clearance between the septum partial upper parts which has height lower than the height of the side attachment wall of each tubs 82 and 92 in the gestalt shown in drawing 8 ) is formed, and cutting fluid can move through free passage section 88a between tubs. That is, the separation tub 82 and the temperature control tub 92 are connected possible [ a free passage ] so that a fluid can move only in the location of the upper part of each tub.

[0082] In the separation section 80, the dirty liquid carried from wire saw equipment is supplied to a magnetic separator 50 and a bag filter 84. A magnetic separator 50 has the capacity to process a lot of cutting fluid for a short time, and is suitable for removing a comparatively large sludge. On the other hand, the bag filter is suitable for removing a comparatively small sludge. If the supply rate of the cutting fluid to each decollator is appropriately set up according to the throughput of each decollator (a magnetic separator 50 and bag filter 84), the magnitude of the sludge contained in cutting fluid, an amount, etc., it is possible to make a sludge separate efficiently. A magnetic separator 50 and the supply rate of the cutting fluid to a bag filter 84 are set as 8:2. However, the gestalt of a decollator may be a gestalt which filters some cutting fluid which was not restricted to this, for example, came out of the magnetic separator 50 with a bag filter 84.

[0083] The cutting fluid from which the sludge was removed by the magnetic separator 50 is carried to the separation tub 82 with a pipe 85 from the edge in the longitudinal direction of a drum 56. Moreover, the cutting fluid from which the sludge was removed

THIS PAGE BLANK (USPTO)

with the bag filter 84 is carried to the separation tub 82 with a pipe 86. The volume of the separation tub 82 is set as about 200 L.
[0084] From opening of pipes 85 and 86, by the septum 88, the cutting fluid which flowed into the separation tub 82 piles up in the separation tub 82 temporarily, and does not flow into the temperature control tub 92 directly. Therefore, the sludge which was able to be removed neither with a magnetic separator 50 nor a bag filter 84 can be made to sediment in the separation tub 82. Consequently, only the supernatant part of the cutting fluid in the separation tub 82 flows into the temperature control tub 92 over a septum 88.
[0085] The sludge which sedimented by the separation tub 82 is returned to a magnetic separator 50 with the sludge absorption pump 87. The opportunity into which can reduce the amount of the sludge in the separation tub 82, and such a sludge is made by this to divide by the magnetic separator 50 again can be obtained. If it does in this way, the desludging engine performance of a purge 72 can be raised.
[0086] In addition, in order to make a sludge sediment [ near the inhalation opening of the sludge absorption pump 87 ], preventing that a sludge soars near the oil level of cutting fluid, it is desirable to prepare a ramp, to collect sludges or to set the location of opening of pipes 85 and 86 as a septum 88, as shown in drawing 8 .
[0087] The supernatant part of the cutting fluid which set separation tub 82 and was formed moves to the temperature control tub 92 through free passage section 88a. The volume of the temperature control tub 92 is set for example, as 400L. The cutting fluid supplied to the temperature control tub 92 does not contain most sludges.
[0088] Thus, the cutting fluid accumulated in the temperature control tub 92 is again returned to the temperature control tub 92, after being sent to the temperature control machine 74 (refer to drawing 7 ) using a pump P3 and lowering temperature. Since it is made to remove a sludge in the separation section 80 before sending cutting fluid to the temperature control machine 74, when a sludge collects in a pipe in the temperature control machine 74, heat exchange effectiveness cannot fall and temperature control of cutting fluid can be performed effectively.
[0089] With this operation gestalt, when the temperature of the cutting fluid in the temperature control tub 92 becomes beyond predetermined temperature, a pump P3 and the temperature control machine 74 are operated, and when the temperature of the cutting fluid in the temperature control tub 92 turns into below predetermined temperature after that, the pump P3 and the temperature control machine 74 are stopped. Therefore, all the cutting fluid held in the temperature control tub 92 is not sent to the temperature control machine 74, and some cutting fluid is sent to it in a predetermined period. Some cutting fluid which temperature control was carried out and was returned, and the remaining cutting fluid in the temperature control tub 92 are mixed by the agitator 94 (stirring), and,

thereby, the temperature of the cutting fluid in the temperature control tub 92 is equalized. If it does in this way, it will be prevented that the temperature of the cutting fluid supplied to the principal part of wire saw equipment changes rapidly compared with the case where the cutting fluid which carried out temperature control is sent to the principal part of direct wire saw equipment. If cutting fluid can be supplied at the temperature stabilized to the principal part of wire saw equipment, since the surface tension of cutting fluid etc. will not change a lot, wire saw equipment can perform stable cutting. Thus, with this operation gestalt, the temperature of the cutting fluid in the temperature control tub 92 is maintainable to a predetermined temperature requirement, operating the temperature control machine 74 effectively.

[0090] On the other hand, under the effect of a room temperature etc., the temperature of cutting fluid may fall and the surface tension of cutting fluid may become large across the predetermined range. In this case, cutting fluid becomes that a cutting slot is fully hard to be supplied, eccritic [ of a sludge ] falls, and cutting resistance increases. Moreover, the fall of the desludging capacity by the magnetic separator may also be produced. Furthermore, coefficient of friction in a cutting edge rises, and wear of an abrasive grain becomes intense. When such, it is advantageous to raise the temperature of cutting fluid using the temperature control machine 72, and to reduce the surface tension of cutting fluid.

[0091] Moreover, the cutting fluid containing a glycol has comparatively high kinematic viscosity, and its temperature dependence of kinematic viscosity is also large. Since it may become that a cutting slot is fully hard to be supplied even if it has the surface tension of the above-mentioned range when kinematic viscosity exceeds 67mm2/s, as for the kinematic viscosity of the cutting fluid supplied between a wire and a rare earth alloy, it is desirable that it is less than [ 67mm2/s ]. Therefore, in using the cutting fluid containing a glycol, while surface tension is in the above-mentioned range, it is desirable to control temperature so that kinematic viscosity may become less than [ 67mm2/s ].

[0092] The cutting fluid by which temperature control was carried out in the temperature control tub 92 is sent to the principal part 30 ( drawing 7 ) of wire saw equipment with a pump P4. The temperature of the cutting fluid supplied between a wire and a rare earth magnet is controlled to become 15 degrees C - 35 degrees C preferably, and is controlled by 20 degrees C - 25 degrees C still more preferably.

[0093] With an above-mentioned operation gestalt, while performing separation removal of a sludge efficiently, performing supply and recovery of cutting fluid cyclically, the surface tension of cutting fluid is maintained in the suitable range by performing temperature control of cutting fluid. If it does in this way, by discharging a sludge appropriately from a cutting slot and maintaining cutting force on low level, cutting efficiency can be raised and precision of a cutting plane can be made high. Therefore, it

enables it to prolong spacing of exchange of cutting fluid remarkably and to continue cutting processing processing continuously over long duration.

[0094] Next, the effect of surface tension to the sectility ability at the time of using glycol content drainage system cutting fluid is explained, referring to drawing 9 and drawing 10 .

[0095] Drawing 9 shows the configuration of the testing machine (evaluator) 10 which conducted the experiment shown in drawing 10 mentioned later. The volume drum 102 by which, as for the testing machine 10, the wire 12 for cutting was wound around the peripheral face, and the revolving shaft was connected to the drive motor (un-illustrating), In two or more pulleys 106 which show again a wire 12 to the volume drum 102 from the volume drum 102 through the cutting section 104 which cuts the cut object (work piece) 14, and the cutting section 104 It has migration equipment 108 to which the cut object 14 can be linearly moved toward a wire 12 (it presses). Moreover, the tension adjustment 110 is formed in the middle of the path of a wire 12. By giving the energization force F to an outside to the movable pulley 112 around which the wire 12 was wound almost, the tension adjustment 110 can give tension to a wire 12, and, thereby, can prevent the slack of a wire 12. further -- the tension adjustment 110 -- a work piece 14 -- pressing -- etc. -- when the tension more than predetermined works on a wire 12, the movable pulley 112 moves inside against the above-mentioned energization force F -- it is constituted so that things can be carried out. While this eases the tension applied to a wire 12, a wire 12 can maintain at a balance the stress given to a work piece 14 (that is, push reliance of a wire is performed by the constant pressure to a work piece 14). As a wire 12, diameter of core wire 0.18mmphi, diameter of result 0.24mmphi, breaking load 7 - 8.5kgf, 40-60 micrometers of diameters of an abrasive grain, and 30 micrometers - 60 micrometers of phenol resin coating thickness were used.

[0096] The cutting fluid supply nozzle 114 is formed above wire 12' of the cutting section 104, and cutting fluid is dropped or injected from a nozzle 114 to wire 12'. The temperature of the cutting fluid which the cutting fluid supplied to wire 12' is discarded, without carrying out the cyclic use of waste water, therefore is supplied to wire 12' is kept almost constant.

[0097] Using this testing machine 10, glycol content drainage system cutting fluid was made dropped at wire 12' from a nozzle 114, and sectility ability was measured. In addition, congruence directional movement of wire 12' was carried out by linear velocity 200 m/min by reversing the hand of cut of the volume drum 102 periodically. Moreover, by setting up appropriately the passing speed of the energization force F and migration equipment 108, the work piece 14 was pressed by 4 Ns of constant pressures to wire 12', and it cut by the constant-pressure load. In addition, the work piece 14 is formed from the rare earth sintered magnet of the letter of a block.

THIS PAGE BLANK (USPTO)

[0098] As cutting fluid, the various glycol content drainage system cutting fluid (YUSHIRO CHEMICAL INDUSTRY [ CO., LTD. ] make: WL-1-WL-5) with which surface tension differs was used at the temperature of about 25 degrees C. The surface tension in 25 degrees C of the used cutting fluid is 33.6 mN/m - 48.9 mN/m. Moreover, cutting oil (YUSHIRO CHEMICAL INDUSTRY [ CO., LTD. ] make: HT-9, 25-degree C surface tension:29.6 mN/m) was made into the reference sample.
[0099] the surface tension [mN/m] of cutting fluid from which drawing 10 was obtained using the testing machine 10, and sharpness fall multiplier alpha[-- %/unit -- a logarithm -- it is the graph which shows relation with time amount] and sectility ability constant gamma [%]. The sectility ability constant gamma is a parameter which shows the sectility ability (sharpness) in the early stages of cutting, and it is thought that it is especially influenced by sludge eccritic etc. The sharpness fall multiplier alpha is a parameter showing the decreasing rate (alpha< 0) of the sectility ability about time amount, and it is thought that especially wear of a wire is shown. A concrete target is a value with which the sectility ability constant gamma and the sharpness fall multiplier alpha are satisfied of the following formulas (1).
[0100] Y=alpha ln (t) +gamma (1)
In a formula (1), t expresses cutting time amount (however, let 3 minutes be one unit), and Y expresses a sectility ability ratio. The sectility ability ratio Y is defined as sectility ability when setting initial sectility ability at the time of using the above-mentioned cutting oil to 100. Sectility ability is determined by measuring the cutting depth of flute formed in the rare earth alloy with the wire. in addition, a formula (1) to the sectility ability constant gamma -- the sectility ability ratio (opposite cutting oil) of 3 minutes after (t= 1) -- expressing -- the sharpness fall multiplier alpha -- a logarithm -- it turns out that the rate of change of the cutting-ability ability to time amount (ln (t)) is expressed.
[0101] When the surface tension in 25 degrees C uses the glycol content drainage system cutting fluid of 33.6 mN/m - 48.9 mN/m so that the graph of drawing 10 may show, the sectility ability constant gamma is under 100 [%], and its sectility ability is lower than the case where the above-mentioned cutting oil is used. However, the sectility ability constant gamma of each water-soluble cutting fluid has exceeded 75 [%], and if sectility ability of this level is obtained, it is possible to cut a rare earth alloy comparatively efficiently. moreover, the case where the glycol content drainage system cutting fluid which has the surface tension of the above-mentioned range is used -- the sharpness fall multiplier alpha -16.5[-- %/unit -- a logarithm -- time amount] -- it is above, and also when it cuts by carrying out long duration continuation, it turns out that sharpness does not fall so greatly. When the value of this sharpness fall multiplier alpha was compared with the sharpness fall multiplier at the time of using cutting water (tap water), it was a value good enough.

[0102] Thus, when using the drainage system cutting fluid of glycol content, a cutting efficiency worsens compared with the case where specific cutting oil is used, but on the other hand since an oil mist etc. does not occur, the advantage that workability becomes good is acquired. Moreover, it is more desirable for drainage system cutting fluid to be unable to pollute an environment easily, and to use drainage system cutting fluid rather than cutting oil at this point. Moreover, since it is comparatively easy to remove a sludge from drainage system cutting fluid, when circulating through and using cutting fluid, drainage system cutting fluid may be an ingredient more suitable than cutting oil.
[0103] It is desirable that the surface tension in 25 degrees C uses the drainage system cutting fluid of about 33 mN/m - about 49 mN/m from an above-mentioned result and the result examined variously. It is desirable that the surface tension in 25 degrees C uses the drainage system cutting fluid (for example, :WL[ by YUSHIRO CHEMICAL INDUSTRY CO., LTD. ]- 2) of 35 mN/m - 45 mN/m especially. It is possible to cut a rare earth alloy efficiently, without causing environmental pollution etc., if such drainage system cutting fluid is used.
[0104] Drawing 11 shows the relation between the magnetism in the sludge recovery side (sludge recovery area) of a magnetic separator, and the flatness of a work-piece cutting plane, and the relation of the magnetism and sludge discharge (amount per hour of the sludge removed from cutting fluid) in the sludge recovery side (sludge recovery area) of a magnetic separator. In addition, the data shown in drawing 11 were obtained under the conditions on which a 1kg [/hour ] sludge is incorporated in cutting fluid from a work-piece cutting plane. Using the gauss meter and the probe (both bell company make), the magnetism at this time (surface inductive flux) contacted the probe to the sludge recovery side, and measured it.
[0105] If the magnetism of a magnetic separator increases so that drawing 11 may show, a sludge discharge will increase in connection with it, and the flatness of a work-piece cutting plane will improve. When there are few sludge discharges from the cutting fluid by the magnetic separator, recovery separation of a sludge is not fully attained but sludge concentration rises. This leads to raising the sludge concentration in the cutting fluid supplied to the part into which processing with a wire is performed. Consequently, since the cutting force to a wire increases and a wire bends, it is thought that the display flatness of a processing side falls. In addition, if a magnetic separator removes a rare earth alloy sludge appropriately, also except that flatness will improve, even if it does not perform whole-quantity exchange of wire cutting fluid, the effectiveness that prolonged continuous running becomes possible is acquired.
[0106] Since the working efficiency of ****** will fall when [ whole ] the time amount which a next polish process takes is taken into consideration if the flatness of a work-piece cutting plane exceeds 100 micrometers, as for flatness, being set to 15 micrometers

or less is desirable, and, also as for magnetism, it is desirable that the flatness of a processing side is adjusted so that it may be set to 15 micrometers or less. For that purpose, it is desirable to set the magnetism in the drum front face of a magnetic separator as 0.27 teslas or more, and it is still more desirable to make it 0.30 teslas or more.

[0107] Again, drawing 1 is referred to. After performing finish-machining by polish to each of the rare earth alloy plate which carried out cutting processing using the above-mentioned approach and preparing a dimension and a configuration, in order to raise long-term dependability, surface treatment is performed to an alloy plate at step S8. After performing a magnetization process by step S9, a neodymium permanent magnet is completed through an inspection process.

[0108] (Example 1) The rare earth alloy was cut using the wire saw equipment shown in drawing 7 . As cutting fluid, the glycol content drainage system cutting fluid (WL-2) by YUSHIRO CHEMICAL INDUSTRY CO., LTD. was used. As a temperature control machine, the automatic temperature control machine (KTC-3B) by Kanto energy machine incorporated company was used. This equipment has the function of both cooling and heating.

[0109] Moreover, as a wire for cutting, the wire (diameter:of core wire0.18mm, thickness:20micrometer of phenol resin, an abrasive grain quality-of-the-material:diamond, diameter:of abrasive grain40-60micrometer, and average abrasive grain spacing:100micrometer) was used. Both-way transit of this wire was carried out by linear velocity 800 m/min, and equipment was operated on new line amount-of-supply:2 m/min and wire tension:30N conditions. As a cut object, the 20mmx40mmx60mm rare earth alloy was tiered seven, it pasted up, and this was contacted on the wire with the fall velocity of 40 mm/min. Cutting of a rare earth alloy was performed having worked the temperature control machine and maintaining the temperature of cutting oil in the range of 25 degrees C - 28 degrees C under the above-mentioned conditions.

[0110] When the rare earth alloy was deeply cut to 180mm and the cutting plane was observed, profile irregularity Ra is 0.8 micrometers or less, Rmax is 7 micrometers or less, and the smooth field was formed. The cut rare earth alloy fulfilled the quality demanded as a magnet used for the motor for voice coils. Moreover, the amount of deflections of a wire was maintained by abbreviation regularity during cutting, and there was no increment in cutting force.

[0111] (Example 1 of a comparison) Except for not working a temperature control machine, the rare earth alloy was cut like the above-mentioned example 1. Although the temperature of glycol content drainage system cutting fluid was 20 degrees C at the beginning, cutting took for progressing, and went up and it amounted to 50 degrees C or more.

[0112] When the rare earth alloy was deeply cut to 180mm and the cutting plane was observed, profile irregularity is falling, the profile irregularity Ra of a cutting plane is 1.5 micrometers or more, Rmax is 15 micrometers or more as the part cut behind, and the field where irregularity is large was formed. The cut rare earth alloy did not fulfill the quality demanded as a magnet used for the motor for voice coils. Moreover, during cutting, the amount of deflections of a wire increased gradually and the increment in cutting force was accepted.

[0113] As explained above, according to the manufacture approach of the above-mentioned rare earth alloy ****, much advantageous effectiveness as taken below is acquired.

[0114] 1. Since the discharge effectiveness of the cutting fluid from a work-piece cutting plane improves, the cutting force which a wire receives is reduced and the continuation cutting activity of long duration is attained.

[0115] 2. It becomes possible to raise the flatness of a work-piece cutting plane. For this reason, the manufacture yield of a product is improved.

[0116] 3. The effectiveness of wire saw cutting over a rare earth alloy is optimized.

[0117] 4. Since the sludge in cutting fluid is efficiently removable, even if it does not exchange cutting fluid frequently, reduce the cutting load of the wire which wins popularity by the work-piece cutting plane, and it becomes possible to raise cutting speed by it.

[0118] 5. Even if collapse of a work piece arises, it is prevented that the quality of a product deteriorates by contact on a wire.

[0119] In addition, although the operation gestalt of this invention has been explained about the manufacture approach of a rare earth alloy plate, this invention is not limited to this. For example, in order to produce a rare earth alloy product and components with processing configurations other than tabular, the cutting process of this invention can be used suitably.

[0120] Moreover, although the processed object was carried out and the operation gestalt using the rare earth alloy magnet ingredient of Nd-Fe-B was explained, since the property for cutting force to be large and to be easy to condense a sludge is common in the whole rare earth alloy, even if this invention uses other rare earth alloys as a workpiece, it can acquire the effectiveness which described the above-mentioned operation gestalt, and the same effectiveness.

[0121] The rare earth alloy magnet produced using the above-mentioned approach has few cutting margins as compared with the case where a rare earth alloy ingot is cut using a peripheral cutting edge, and is suitable for manufacturing a thin magnet (0.5-3.0mm in for example, thickness). In recent years, since the rare earth magnet used for a voice coil motor is becoming still thinner, if the above-mentioned thin rare earth alloy magnet

manufactured using the approach of this invention is attached in a voice coil motor, a small voice coil motor with the high engine performance can be offered.

---

[Translation done.]

THIS PAGE BLANK (USPTO)

---

## DESCRIPTION OF DRAWINGS

---

[Brief Description of the Drawings]
[Drawing 1] It is the flow chart which shows the production procedure of a Nd-Fe-B permanent magnet.
[Drawing 2] (a) is the front view showing the ingot block fixed to the work-piece plate, and (b) is the side elevation.
[Drawing 3 A] It is the perspective view showing the principal part of the wire saw equipment suitably used with the operation gestalt of this invention.
[Drawing 3 B] It is the front view showing the principal part of said wire saw equipment suitably used with the operation gestalt of this invention.
[Drawing 3 C] It is the front view showing the principal part of other wire saw equipments suitably used with the operation gestalt of this invention.
[Drawing 4] It is the outline block diagram showing the cutting fluid circulation system of said wire saw equipment.
[Drawing 5] It is the perspective view showing the magnetic-separator equipment with which said wire saw equipment was equipped.
[Drawing 6] It is the sectional view of a wire.
[Drawing 7] Drawing 4 is the outline block diagram showing the cutting fluid circulation system of the wire saw equipment of another gestalt.
[Drawing 8] It is the perspective view showing the purge with which the circulation system shown in drawing 7 was equipped.
[Drawing 9] It is the testing machine used in order to investigate the relation between that of glycol content drainage system cutting fluid, and sectility ability.
[Drawing 10] It is the graph which shows the relation between that of glycol content drainage system cutting fluid, and sectility ability.
[Drawing 11] It is the graph which shows the relation between the magnetism of a magnetic separator, and the flatness of a work-piece cutting plane.

[Description of Notations]
20 Ingot of Rare Earth Alloy
22 Adhesives
24a-24c Block of an ingot (ingot mounting block)
26 Work-Piece Plate
28 Base Plate made from Carbon
29 Cutting Fluid Delivery Pipe
29a Slit-like nozzle
30 Principal Part of Wire Saw Equipment
32 Wire
34a-34c Maine roller (multi-slot roller)
36 Nozzle
37 Recovery Drain of Slurry
37' Processing machine drain
38 Cutting Fluid Tub
40 Wire Saw Equipment
42 Cutting Fluid Service Tank
44 1st Circulation Pipe
46 2nd Circulation Pipe
48 Cutting Fluid Recovery Tank
49 3rd Circulation Pipe
50 Magnetic Separator
52 Used Cutting Fluid Containing Sludge (Dirty Liquid)
54 ******
54a Opening prepared in ******
56 Drum
57 Squeezing Roller
58 Scraper
59 Sludge Box

---

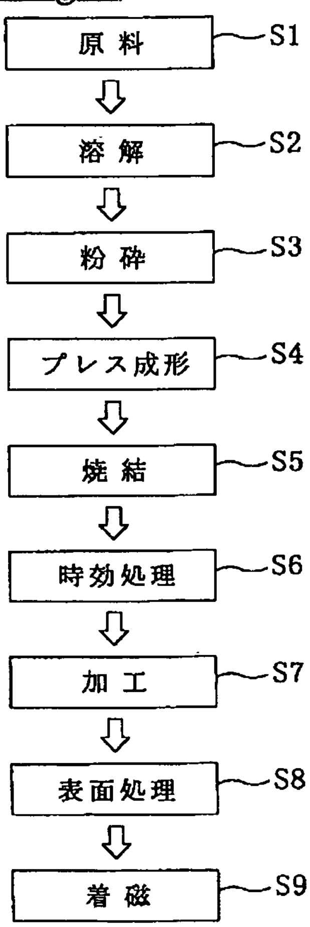
[Translation done.]

---

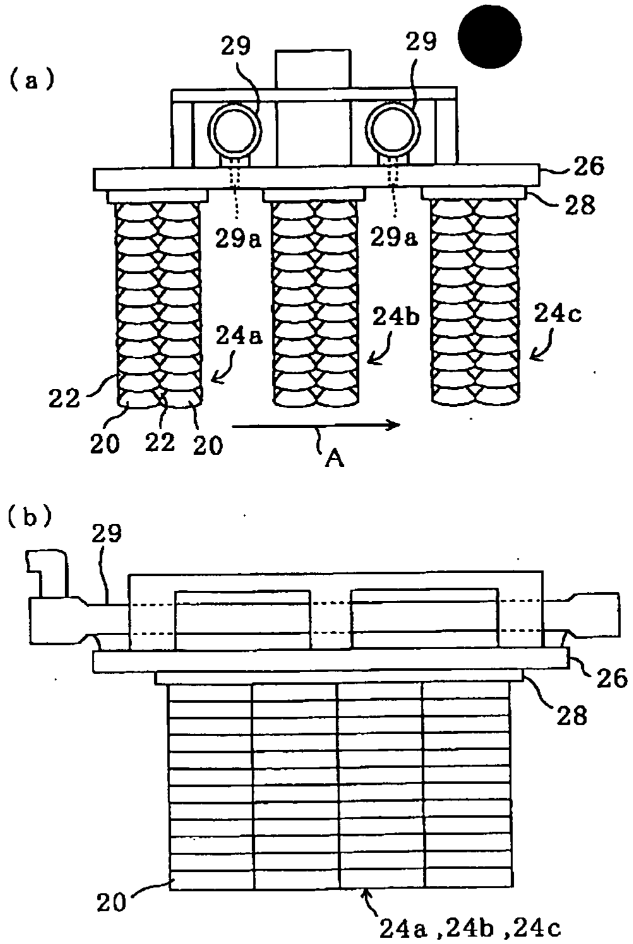
DRAWINGS

---

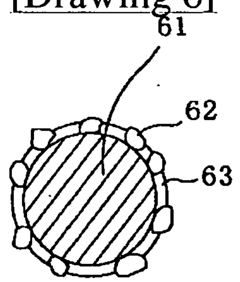
[Drawing 1]




[Drawing 2]

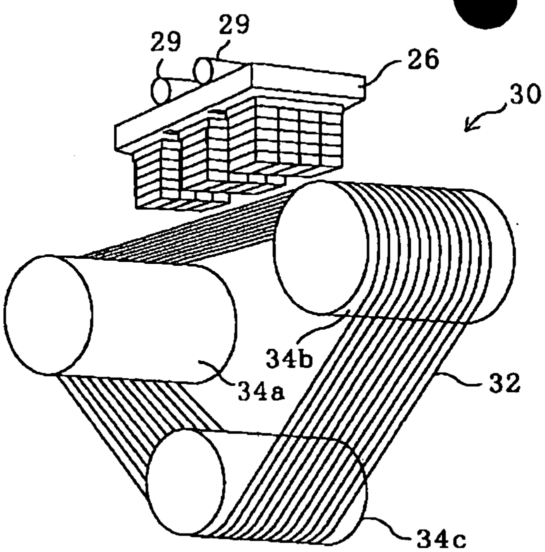



[Drawing 6]

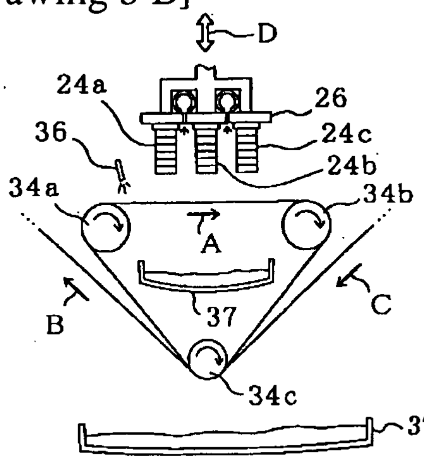



[Drawing 3 A]

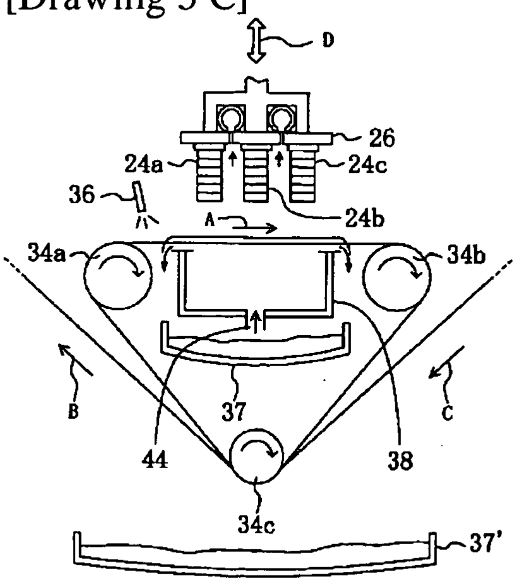
THIS PAGE BLANK (USPTO)



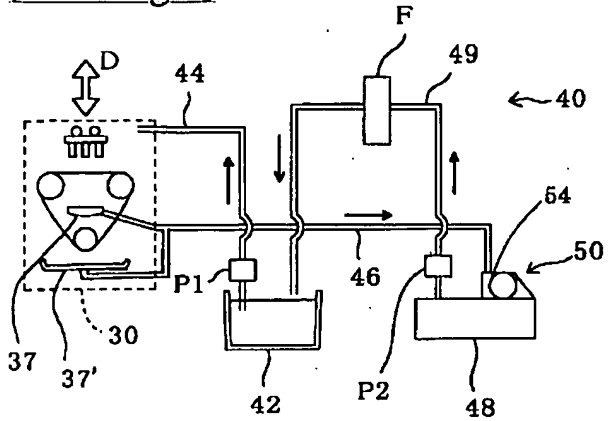

[Drawing 3 B]



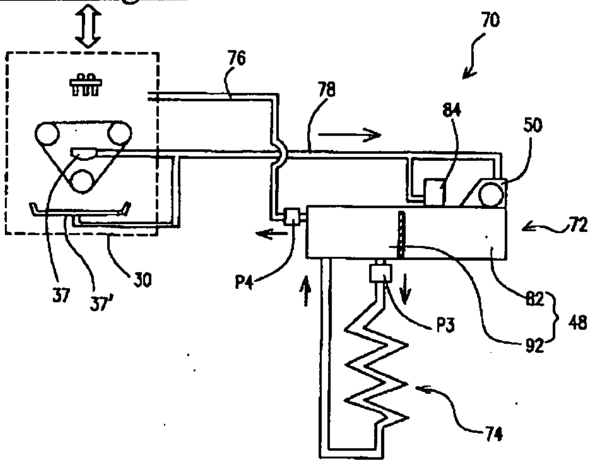

[Drawing 3 C]



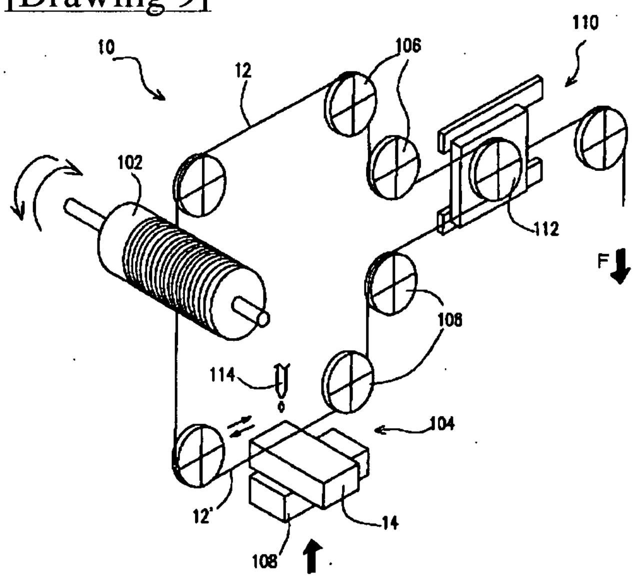
[Drawing 4]



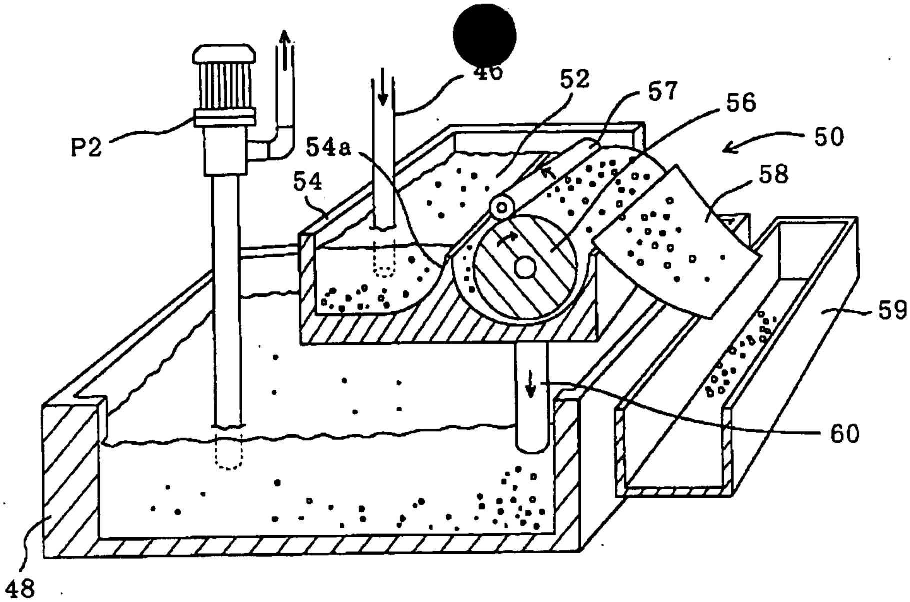

[Drawing 7]



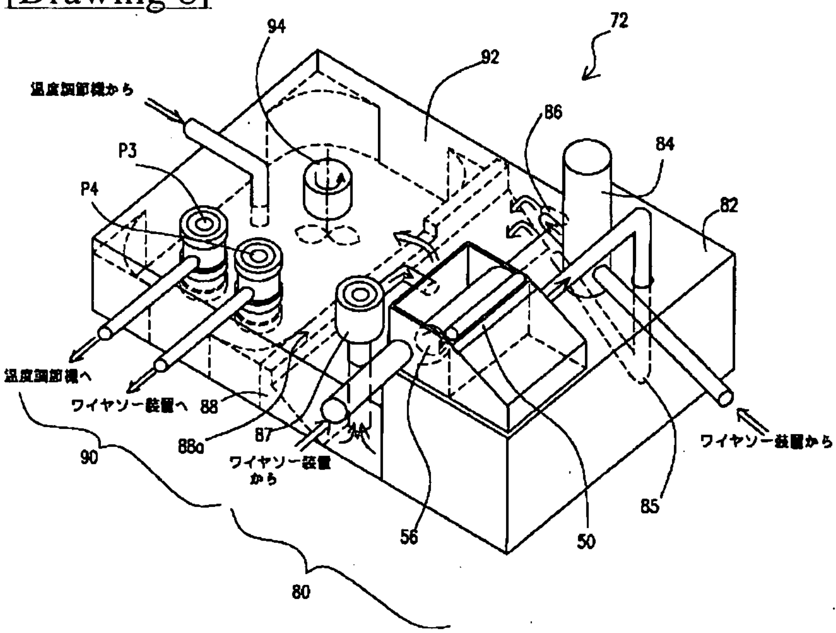

[Drawing 9]

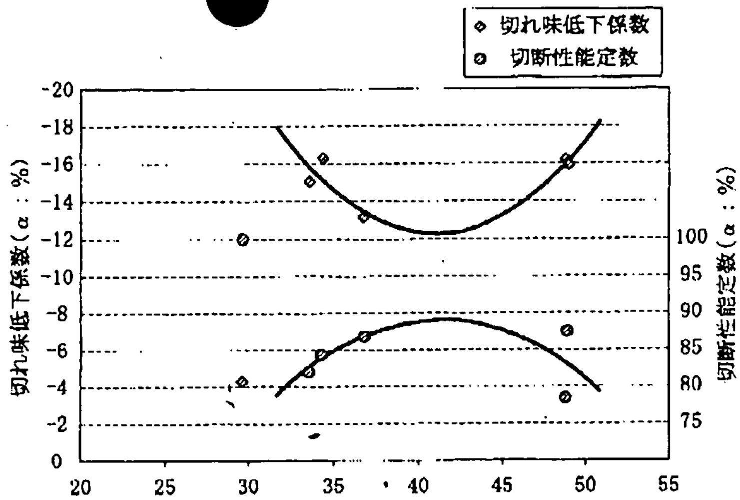



[Drawing 5]


P2
46
52
57
56
50
54a
54
58
59
60
48

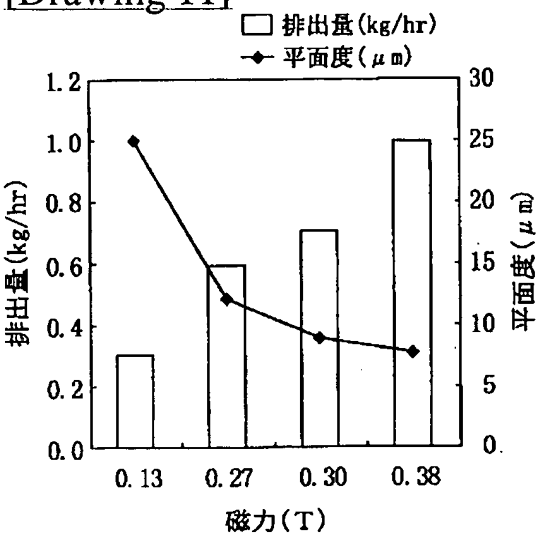
[Drawing 8]


94
72
92
温度調節機から
86
84
P3
82
P4
温度調節機へ
ワイヤソー装置へ
88
87
88a
90
ワイヤソー装置
から
ワイヤソー装置から
85
56
50
80




[Drawing 10]

[Drawing 11]




---

[Translation done.]